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Lifestyle behavior change for preventing the progression of chronic kidney disease: a systematic review

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ABSTRACT

Objectives: Modifying lifestyle can prevent the progression of chronic kidney disease (CKD) but the specific elements which lead to favourable behaviour change are not well understood. We aimed to identify and evaluate behaviour change techniques and functions in lifestyle interventions for preventing the progression of CKD.

Design: Systematic review.

Data sources: MEDLINE, EMBASE, CINAHL and PsycINFO.

Eligibility criteria: Trials of lifestyle behaviour change interventions (including diet, physical activity, smoking and/or alcohol) published to September 2018 in adults with CKD stages 1-5.

Data extraction and synthesis: Trial characteristics including population, sample size, study setting, intervention, comparator, outcomes and study duration, were extracted. Study quality was independently assessed by two reviewers using the Cochrane risk of bias tool. The Behaviour Change Technique Taxonomy v1 was used to identify behaviour change techniques (e.g. goal setting) and the Health Behaviour Change Wheel was used to identify intervention functions (e.g. education). Both were independently assessed by three reviewers.

Results: In total, 26 studies involving 4,263 participants were included. Risk of bias was high or unclear in most studies. Interventions involved diet (11), physical activity (8) or general lifestyle (7). Education was the most frequently used function (21 interventions), followed by enablement (18), training (12), persuasion (4), environmental restructuring (4), modelling (2) and incentivisation (2). The most common behaviour change techniques were behavioural instruction

(23 interventions), social support (16), behavioural demonstration (13), feedback on behaviour (12) and behavioural practice/rehearsal (12). Eighteen studies (69%) showed a significant improvement in at least one primary outcome, all of which included education, persuasion, modelling and incentivisation.

Conclusion: Lifestyle behaviour change interventions for CKD patients frequently used education, goal setting, feedback, monitoring and social support. The most promising interventions included education and used a variety of intervention functions (persuasion, modelling and incentivisation).

Keywords: chronic kidney disease (CKD), lifestyle, diet, exercise, behavior change techniques, Health Behavior Change Wheel, Behavior Change Technique Taxonomy v1, systematic review.

ARTICLE SUMMARY

Strengths and limitations of this study

- We used comprehensive, evidence-based frameworks to identify and describe behaviour change techniques and intervention functions in lifestyle behavioural interventions for patients with CKD.
- Coding of behaviour change techniques and intervention functions was systematically and independently conducted by three researchers, and risk of bias was assessed.
- Summary estimates could not be ascertained due to the heterogeneity of interventions and outcome measures.

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Competing interests statement

The authors do not have any competing interests or conflicts of interest to declare.

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INTRODUCTION

Preventing the progression of CKD is a high priority for patients and clinicians, to reduce the requirement for dialysis.[1-3] Lifestyle interventions which modify behavioural risk factors such as poor diet and low physical activity can prevent progression of CKD and life-threatening complications and improve quality of life and survival.[4-6] Addressing behaviour change is particularly relevant in CKD as lifestyle modification can be challenging. Poor adherence to diet, medication and other treatments is common in CKD.[7] Barriers to modifying lifestyle include low health literacy, conflicts with cultural norms, complicated nutritional requirements and safety concerns.[7-11]

Guidelines recommend the explicit use of behaviour change for addressing lifestyle risk factors when designing and reporting interventions for patients with CKD.[12,13] However, it is uncertain which aspects of lifestyle behaviour change interventions are the most effective, and reporting of behavioural components is often unclear, making implementation in practice problematic.

The Behaviour Change Technique Taxonomy v1 was developed to provide a comprehensive framework that integrates behaviour change techniques used in interventions.[14] The Taxonomy was further synthesized into a framework, the Health Behaviour Change Wheel which describes the intervention functions necessary to change health behaviors.[15] The Health Behaviour Change Wheel provides a broad, overarching framework in which to characterize behaviour change interventions while the Taxonomy identifies specific techniques related to individual behaviours. The intervention functions described in the Health Behaviour Change Wheel can be delivered by a variety of behaviour change techniques. For example, the intervention function, “education”, outlined in the Wheel, can include the behaviour change techniques “instruction on how to perform the behaviour” and “information about antecedents”, detailed in the Taxonomy. Similarly, the

intervention function "incentivisation" can incorporate techniques such as "feedback on behaviour" and "rewards".

Behaviour change interventions using the Wheel and the Taxonomy can effectively change lifestyle behaviours. For example, a text-messaging and pedometer program improved physical activity in people at high risk of type 2 diabetes[16], a digital healthy eating program increased consumption of fruit and vegetables and sustained this over a 6-month period[17] and a digital behaviour change program achieved significant weight loss results in individuals at risk of type-2 diabetes.[18] The Taxonomy and the Wheel are recommended approaches to modify lifestyle risk factors for chronic disease prevention.[12,16,18] However, these frameworks have not been used in designing and reporting behaviour change strategies in lifestyle interventions for patients with CKD.

We aimed to identify and evaluate behaviour change techniques and intervention functions used in lifestyle interventions for preventing the progression of CKD. This may inform the development of effective and replicable behaviour change interventions for the prevention of CKD, leading to improvements in patient outcomes.

METHODS

The review protocol was registered with the international prospective register of systematic reviews (http://www.crd.york.ac.uk/PROSPERO; registration number CRD42019106053). We used the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Statement[19] and checklist to report this systematic review (Supplementary File S1).

Selection criteria

We included randomized trials of lifestyle behaviour change interventions (including, but not restricted to diet, physical activity, smoking and alcohol consumption) in adult patients (aged over

18 years) with CKD stages 1-5 and not requiring renal replacement therapy. We did not apply restrictions based on outcomes or language. Studies including a combination of pharmacological therapy and lifestyle were included but trials involving only pharmacological therapies were excluded.

Literature search

A comprehensive search was conducted in MEDLINE (1946 to 20 September 2018), Embase (1996 to 20 September 2018), CINAHL (1982 to 20 September 2018) and PsycINFO (1806 to 20 September 2018) using Medical Subject Heading (MeSH) terms relating to CKD, and lifestyle behaviour change interventions (Supplementary File S2), and reference lists of relevant articles and reviews. Author N.E. screened the studies by title and abstract and assessed full-text articles for eligibility. Those that did not meet the inclusion criteria were excluded.

Data extraction and critical appraisal

The trial characteristics relevant to the population, sample size and study setting as well as intervention (type, mode of delivery, use of theory, intervention functions (as described in the Health Behaviour Change Wheel[15]) and behaviour change techniques (as described in the Behaviour Change Technique Taxonomy v1[14])), comparator, outcomes and study duration, were extracted and tabulated. We assessed the risk of bias using the Cochrane tool for randomized studies.[20] N.E. and K.M. assessed the risk of bias in each study independently and any differences were resolved by discussion.

Analysis of intervention functions and behaviour change techniques

The Behaviour Change Technique Taxonomy v1 (the 'Taxonomy') and Health Behaviour Change Wheel (the 'Wheel') are comprehensive tools for identifying behavioural components in interventions and how frequently they occur.[14,15] The two frameworks are complementary and in

addition to designing interventions, they have been used as a method for identifying behavioural components in public health interventions and clinical trials.[21] The tools have been used in previous systematic reviews to identify behaviour change techniques and functions in health interventions.[22-28]

Behaviour change techniques

The Behaviour Change Technique Taxonomy consists of 93 behaviour change techniques, such as goal-setting, self-monitoring, social support and re-structuring the physical environment (see Supplementary Table S1 for the full taxonomy). The techniques are grouped into 16 domains: goals and planning, feedback and monitoring, social support, shaping knowledge, natural consequences, comparison of behaviour, associations, repetition and substitution, comparison of outcomes, reward and threat, regulation, antecedents, identity, scheduled consequences, self-belief and covert learning.

Intervention functions

There are nine intervention functions in the Wheel: education, persuasion, incentivisation, coercion, training, enablement, modelling, environmental restructuring and restrictions.[15] These are activities designed to change behaviours and include one or more behaviour change techniques. Definitions of each intervention function have been described by Michie et al and were used to inform decisions about what functions were present in each study.[15]

Authors N.E. and K.M completed online training for interpreting the Wheel and the Taxonomy to ensure consistency and reliability of coding.[29] N.E., K.M. and V.S. independently read intervention descriptions line-by-line to locate text matching a definition of an intervention function[15] and the description of behaviour change techniques from the BCTTv1 coding frame (Table S1). Each of the 93 behaviour change techniques were indicated as either present or absent in a standardized data

extraction form. A behaviour change technique had to be explicitly described to be coded and included in the analysis. The authors compared the codes and discussed discrepancies to reach consensus.

RESULTS

Literature search and study characteristics

The literature search yielded 10,043 citations from which 26 studies (n= 4,263 participants) were eligible and included in the review (Figure 1). Study characteristics are shown in Table 1. The studies were conducted in 15 countries.

Risk of bias assessment

Overall, the reporting of studies was relatively incomplete, particularly for the blinding of participants and personnel which was missing or unclear in every study (Figure 2). Allocation concealment was unclear or at high risk of bias in 20 (77%) studies. Blinding of outcome assessment was also poorly reported with 19 studies showing high or unclear risk of bias for this domain. Domains that performed better were selective reporting with low risk of bias in 21 studies, random sequence generation with low risk of bias in 17 studies and incomplete outcome data showing low risk of bias in 13 studies.

Characteristics of the interventions

Across the interventions assessed in the 26 studies included, 11 were dietary interventions, 8 involved physical activity, and 7 used any combination of diet, physical activity, weight reduction and/or smoking cessation (lifestyle).

Five studies were informed by theory, three used the Trans-Theoretical Model[30,31], one used self-regulation theory[32] and another was informed by contemporary behavioural theory, in particular the

self-management approach.[33] Two studies used Motivational Interviewing[34,35], a counselling approach which involves behaviour change strategies.[36]

Only three studies included family members, friends or partners in the intervention to facilitate participant's behaviour change (Supplementary Table S2).[31,37]

Behaviour change techniques

Table 2 outlines the number of behaviour change techniques present in each lifestyle behaviour change intervention. The number of behaviour change techniques used across interventions ranged from 2 to 20.

The top five most frequently observed behaviour change techniques were instruction on how to perform the behaviour (23 interventions, 88%), social support (16, 62%), demonstration of the behaviour (13, 50%), feedback on behaviour (12, 46%), and behavioural practice/rehearsal (12, 46%). Of the 93 possible behaviour change techniques that could have been used, 12 techniques were used in more than 20% of trials, 27 were used at least once and 54 were never used. The mean number of behaviour change techniques was 5, the median was 4 and the range 2-20.

The two studies with the highest number of behaviour change techniques (20 and 18 in each study) were both informed by theory, with a particular focus on self-regulation and self-management.[32,33]

Intervention functions

Table 3 lists the intervention functions present in each study (education, enablement, training, persuasion, modelling, incentivisation, environmental restructuring, coercion and restrictions). The number of functions used across interventions ranged from one to seven.

Education: Education was used most frequently as an intervention function, present in 21 (81%) interventions (Table 3). Examples of educational strategies were: nutritional label reading[38,39], a resistance training booklet for home-based exercise[40], a lecture/workshop about exercise recommendations with demonstrations[30], online education modules on lifestyle modification[41] and a written "six-tip diet" checklist.[42]

Enablement: Eighteen (69%) interventions used enablement. Examples include Motivational Interviewing to improve self-management of diet, lifestyle and physical activity[32,43], supportive telephone calls matching stages of behaviour change[30], self-management techniques to foster self-efficacy[38,39,44] and arranging support from friends and family members and "buddy" visits.[31,33] Four interventions were specifically designed using a self-management approach and assessed self-efficacy as an outcome.[32,33,39,44]

Training: Twelve (46%) interventions included training as an intervention function. Training was used in every intervention targeting physical activity but only used in two dietary interventions and two lifestyle interventions. Examples of training include home-based exercise training, guided exercise training in a gym[40], physical therapy or cardiac rehabilitation facility[45] or hospital[34] and interactive cooking classes.[39]

Persuasion: Four (15%) interventions used persuasion as an intervention function. A dietary intervention aimed to persuade participants about dietary salt intake by displaying test tubes of salt content alongside a range of high-salt food items.[46] In another dietary intervention, positive thinking was applied to participant's goals and dieticians praised progress and focused on positive results.[33] Similarly, a lifestyle intervention used positive reinforcement to increase confidence and celebrate successes related to behaviour change and also discussed lack of exercise, poor dietary habits, risks

of not exercising and associated consequences.[31] Only one physical activity intervention used persuasion in designing and displaying printed health messages to promote exercise.[30]

Environmental re-structuring: Four (15%) interventions used environmental restructuring. Two involved placing exercise equipment in the home environment (exercise bicycle, Theraband, weights and Swiss ball)[40,43] and two included adding food products and equipment into the home environment (low sodium/protein meals and water bottles).[33,47]

Modelling: Two (8%) dietary interventions incorporated modelling as an intervention function. Educators used food models and household measuring utensils to model appropriate food portion sizes[46] and food tastings provided an example of low protein meals.[33]

Incentivisation: Two (8%) studies used incentivisation, one in the form of "appreciation gifts" including certificates and mugs[33] and another included "self-rewards" chosen by participants.[32]

Coercion and restrictions: These functions were not used in any of the interventions.

Outcomes

A description of primary outcomes and results reported in studies is included in Table 4. Primary outcomes of studies in this review were diverse and were mainly physiological metrics (for example, eGFR, blood pressure, peak VO2 and sodium or albumin excretion). Only six studies included patient-reported and/or behavioural primary outcomes such as quality of life, fatigue, knowledge, self-efficacy, self-management, exercise and health behaviors.[30,31,44,45,48,49]

Eighteen studies (69%) showed a significant improvement in at least one primary outcome and all of these studies included education, persuasion, modelling and incentivisation as an intervention

function (see Supplementary Table S3). A meta-analysis of the data was not possible due to heterogeneity of outcome measures across the included studies. The heterogeneity of outcomes also meant we could not link outcomes with specific behaviour change techniques. Many studies are likely to be underpowered to detect modest effects, and so the absence of a statistically significant effect should not be regarded as evidence of no effect.

DISCUSSION

Behaviour change interventions in trials in patients with CKD mostly focused on diet and physical activity. The primary outcomes of the trials were diverse and most were biochemical outcomes (e.g. eGFR, blood pressure, peak VO2 and sodium or albumin excretion), with few clinical or patient-reported and/or behavioural outcomes such as quality of life, fatigue, knowledge, self-efficacy and self-management.[30,31,38,39,44,45] Only five interventions were underpinned by theory. The most frequently used intervention function was education, followed by enablement and training. Persuasion, environmental restructuring, modelling and incentivisation were used less frequently. Coercion and restrictions (which includes regulation) were not used in any of the studies. The top five most common behaviour change techniques were instruction on how to perform the behaviour, social support, demonstration of the behaviour, feedback on behaviour, and behavioural practice/rehearsal. Identity, scheduled consequences and covert learning were not used in any of the studies. No association between frequency of functions or behaviour change techniques and the effect of interventions on outcomes could be identified.

The use of multiple behaviour change techniques does not necessarily lead to better outcomes and some evidence suggests that fewer techniques and the right combinations of techniques suited to the context are more effective.[50-52] Education was the most frequent intervention function used across the studies, which may be because it has been consistently shown that patients with CKD lack awareness about lifestyle risk factors and have low health literacy.[10,11,53] Specifically, the behaviour

change technique, "instruction on how to perform the behaviour", was the most frequently reported technique, used in all interventions except two. We suggest this is highly applicable because dietary interventions can involve complex dietary restrictions of sodium, protein, potassium and phosphate. Patients have sought practical advice about how to implement these restrictions.[54] However, most educational strategies used a didactic approach, with health professionals verbally conveying information or providing written materials. Patients with CKD prefer multiple problem-solving and collaborative approaches, in partnership with health professionals.[54] Also, written materials for patients with CKD have a reading grade of 9 (age 14-15 years), which is higher than the recommended level (grade 5).[10]

The intervention function "training" was used in every study targeting physical activity but was only used in two dietary interventions. Patients with CKD are overwhelmed by dietary information which can be complex, restrictive, and insensitive to cultural norms.[54] A recent review of educational interventions for CKD patients found that including practical skills and workshops was associated with better outcomes.[55] For example, a low-salt program for Bangladeshi patients with CKD in the United Kingdom included cooking and educational sessions facilitated by Bengali workers in a community kitchen. It targeted both patients and family members who cooked their own low-salt version of Bangladeshi recipes and led to a reduction in salt intake and reduced blood pressure for participants.[37] Approaches to enabling and training patients for behaviour change incorporating hands-on training may be more effective.

Our findings are similar to recent reviews of behavioural interventions for other conditions (cardiovascular disease, obesity, rheumatoid arthritis, prostate cancer and diabetes), which also found that behavioural interventions are not well-reported, not informed by theory and have diverse outcomes and modes of delivery.[25-27,51,56] The behaviour change techniques associated with goals and planning, feedback and monitoring and social support have also been frequently used in

behaviour changes interventions in patients with other chronic conditions. These techniques are proven strategies for behaviour change and in line with evidence-based recommendations for lifestyle modification.[12,13,57]

We identified and described the behaviour change techniques and intervention functions in lifestyle behavioural interventions for patients with CKD with comprehensive evidence-based frameworks. Coding of behaviour change techniques and intervention functions was systematically and independently conducted by three researchers, and risk of bias was assessed. Potential limitations relate to poor reporting. Some interventions may have used behaviour change techniques or intervention functions in their study but did not report them, or details of techniques were unclear. We contacted authors and examined all associated supplementary materials and papers to collect more information.

Lifestyle behaviour change interventions for patients with CKD appear to integrate recommended and proven behaviour change techniques and intervention functions. These techniques such as goals and planning and self-monitoring are important but focus on individual agency rather than external factors. Interventions could be improved by considering the context of behaviour change and the social and physical environment of participants. For example, most of the interventions for physical activity focused on structured exercise programs and a reliance on equipment (e.g. exercise bikes). Patients with CKD need to be able to integrate physical activity in to their daily lifestyle.[58] However, only one intervention for physical activity gave instructions on how to incorporate physical activity to fit in with daily activities and in environments easily accessible to patients, without the use of equipment.[59] This study reported improvements in cardiopulmonary and functional capacities of overweight patients with CKD.

Optimizing the social environment and arranging support from friends, family and the community may also improve lifestyle behaviour change interventions for patients with CKD. Family support was used rarely in interventions in this review and only included in two studies.[31,37] However, informal caregivers play an important role in the management of CKD and are often required to change their own lifestyle behaviours to support patients with CKD.[60] Characteristics of effective educational interventions for patients with CKD involved the patient's family.[55]

The quality of the design and reporting of lifestyle behaviour change interventions for patients with CKD requires explicit description of behavioural strategies to ensure interventions are generalizable and replicable. There are numerous evidence-based guidelines that recommend the explicit use of behaviour change techniques for addressing lifestyle risk factors in chronic disease prevention and these may be better utilized when designing and reporting interventions for patients with CKD. Recently the National Institute of Health and Care Excellence in the UK published comprehensive guidelines specific to behavioural interventions and lifestyle modification.[12] The World Health Organization's recommendations on behaviour change support this and further reinforce the need to consider the social and environmental determinants of health in changing lifestyle behaviors.[57]

CONCLUSION

Lifestyle interventions in trials conducted in patients with CKD mostly focus on goals and planning, feedback and monitoring and education. However, we suggest that interventions may be improved by using interactive and tailored training, and strategies to help patients incorporate lifestyle modification in their daily activities, and physical and social environments. Explicit application of behaviour change taxonomies may help to increase the effect of lifestyle behaviour change interventions for improved health outcomes in patients with CKD.

Contributors

Research idea and study design: NE, AT, JCC; data acquisition: NE, KM, VS; data analysis/interpretation: NE, AT, JCC, AB, KM, VS; statistical analysis: NE; supervision or mentorship: AT, JCC, AB.

Competing interests

None declared.

Patient consent for publication

Not required.

Data sharing statement

No additional data are available.

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TABLES AND FIGURES

SUPPLEMENTARY MATERIAL

Table 1. Characteristics of included studies

Study	N	CKD Stage	Age (years)	Country	Intervention	Comparator	Primary Outcomes	Study duration (months)
Dietary interventions								
Campbell (2008)	56	CKD4-5	>18	Australia	Individualized nutritional counselling & regular follow up	Usual care	Body composition	3
Clark (2018)	590	CKD3	18-80	Canada	Coaching to increase water intake (drinking containers & water vouchers also provided)	Coaching to maintain usual fluid intake	Change in eGFR	12
De Brito-Ashurst (2013)	56	eGFR <60 mL & BP>130/80 or taking BP medication; Bangladeshi origin	18-74	United Kingdom	Community cooking education sessions facilitated by Bengali workers	Usual care	Reduction in systolic/diastolic BP	6
Dussol (2005)	63	Type I/II diabetic nephropathy, eGFR60-100 mL	40 - 72	France	Low-protein diet with telephone calls every 6 weeks to help change dietary habits	Usual-protein diet	Decline GFR and 24-hour albumin excretion rate	24
MDRD Study (1995)*	840	eGFR 13-55 mL	18-70	United States	Low protein diet with dietician support	Moderate, low & very low protein diets compared	Decline eGFR, dietary satisfaction	45
Mekki (2010)	40	eGFR 60-90mL	47-75	Algeria	Nutritional advice based on Mediterranean diet	Usual care	Dyslipidemia	3
Meuleman (2016)	138	eGFR≥20 mL	≥18	The Netherlands	Sodium restricted diet with self-management, education, motivational interviewing & self-monitoring	Usual care	Sodium excretion & BP	3
Paes-Barreto (2013)	89	CKD3-5	≥18	Brazil	Intense counselling/education on low protein diet	Standard counselling	Change in protein intake	4
Pisani (2016)	57	CKD3b-5	>18	Italy	Low protein, phosphate & sodium diet, '6-tips diet' checklist	Non-individualized, moderately low protein diet	Protein intake, metabolic parameters and adherence	6

Study	N	CKD Stage	Age (years)	Country	Intervention	Comparator	Primary Outcomes	Study duration (months)
Rosman (1989)	247	CrCl 10-60 ml/min	15-73	The Netherlands	Dietary protein restriction & dietician visits every 3 months	Usual care	Adherence	24
Saran (2017)	58	CKD3-4	>18	United States	Dietary sodium restriction (<2g sodium per day)	Usual diet	Change in hydration status	1
Physical activity interventions								
Aoike (2015)	29	CKD3-4	18-70	Brazil	Home-based moderate-intensity aerobic exercise program	Usual care	Cardiopulmonary/ functional, BP, CrCl, eGFR	3
Barcellos (2018)	150	CKD2-4	>18	Brazil	Aerobic & resistance training	Usual care	Change in eGFR	4
Greenwood (2015)	20	CKD3-4	18-80	United Kingdom	Resistance & aerobic training (3 days per week)	Usual care	Change in eGFR	12
Kao (2012)	94	eGFR≥15 mL	≥39	Taiwan	Group education lecture; individual exercise program Trans-Theoretical Model	Not specified	Exercise behaviour, depression, fatigue	3
Leehey (2016)	32	CKD2-4	49-81	United States	Aerobic & resistance training, home exercise (plus dietary management)	Dietary management	Urine protein to creatinine ratio	12
Rossi (2014)	107	CKD3-4	≥18	United States	Guided exercise twice a week plus usual care	Usual care	Physical function, quality of life	3
Tang (2017)	90	CKD1-3	18-70	China	Individualized exercise program (education & home-based aerobic exercise)	Usual care	Physical function, self-efficacy, anxiety, depression, quality of life	3
Van Craenenbroeck (2015)	40	CKD3-4	≥18	Belgium	Home-based aerobic training program (4 daily cycling sessions, 10 minutes each)	Usual care	Peripheral endothelial function	3
Lifestyle interventions								
Flesher (2011)	40	CKD3-4	18-80	Canada	Individual dietary counselling, group nutrition & cooking classes, exercise program	Usual care	Composite eGFR, TC, urinary sodium, urinary protein & BP	12

Study	N	CKD Stage	Age (years)	Country	Intervention	Comparator	Primary Outcomes	Study duration (months)
Howden (2013)	83	CKD3-4	18-75	Australia	Multi-disciplinary care, lifestyle & aerobic /resistance training	Usual care	Change in CRF	12
Ishani (2016)	601	eGFR <60	>18	United States	Care by a multi-disciplinary team using a telehealth device	Usual care	Composite death, hospitalization, emergency visits & admission to a nursing facility	20
Jiamjariyapon (2017)	442	CKD3-4	18-70	Thailand	Integrated care by multidisciplinary team & community care workers. Group counselling, home visits	Usual care	Change in eGFR	24
Joboshi (2017)	65	Overt proteinuria & clinically diagnosed CKD	38-86	Japan	Self-management program	Standard education	Self-efficacy & self-management behaviour	3
Patil (2013)	76	Diabetic nephropathy	30-70	India	Low-calorie diet, physical activity and behaviour	ACE inhibitor therapy	24-hr urine protein BMI	6
Teng (2013)	160	eGFR≥30 mL/min/1.73 m2	≥ 20	Taiwan	Lifestyle modification program based on Trans-Theoretical Model	Standard education	Health behaviours, knowledge, physical function	12

Abbreviations: eGFR, estimated glomerular filtration rate; BP, blood pressure; MDRD, Modification of Diet in Renal Disease study; CrCl, creatinine clearance; TC, total cholesterol; CRF, cardiorespiratory fitness.

*MDRD study described in two main articles: Gillis et al (1995) and Coyne et al (1995)

Table 2. Cross matrix of behaviour change techniques and lifestyle behaviour change trials

	Meuleman (2016)	MDRD Study (1995)	De Brito-Ashurst (2013)	Paes-Barreto (2013)	Campbell (2008)	Rosman (1989)	Dussol (2005)	Pisani (2016)	Saran (2017)	Clark (2018)	Mekki (2010)	Tang (2017)	Kao (2012)	Greenwood (2015)	Rossi (2014)	Aoike (2015)	Barcellos (2018)	Van Craenenbroeck (2015)	Leehey (2016)	Howden (2013)	Ishani (2016)	Joboshi (2017)	Teng (2013)	Flesher (2011)	Jiamjariyapon (2017)	Patil (2013)
1. Goals and planning	**Diet**											**Physical Activity**								**Lifestyle**						
1.1. Goal setting (behavior)	■	■	■		■							■	■		■					■						
1.2. Problem solving	■	■			■							■								■		■	■			
1.3. Goal setting (outcome)	■																				■	■	■	■		
1.4. Action planning	■											■	■		■											
1.5. Review behavior goal(s)	■				■							■											■			
1.7. Review outcome goal(s)	■	■	■			■								■		■					■	■				
1.8. Behavioral contract	■	■										■	■													
1.9. Commitment		■																								
2. Feedback and monitoring																										
2.1. Monitoring of behavior by others without feedback							■	■			■										■					■
2.2. Feedback on behavior		■	■	■	■	■			■			■	■			■					■	■			■	
2.3. Self-monitoring of behavior	■	■										■	■	■						■	■	■				
2.4. Self-monitoring of outcome(s) of behaviour	■	■																						■		
2.6. Biofeedback	■	■																								
2.7. Feedback on outcome(s) of behavior	■																									
3. Social support																										
3.1. Social support (unspecified)	■		■	■	■		■					■	■			■	■	■	■		■	■	■	■	■	
3.2. Social support (practical)						■													■							
3.3. Social support (emotional)	■	■							■					■												
4. Shaping knowledge																										
4.1. Instruction on how to perform the behavior	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■		■	■	■	■
4.4. Behavioral experiments			■																							
5. Natural consequences																										
5.1. Information about health consequences	■		■		■				■			■	■										■			
5.2. Salience of consequences				■																						
5.4. Monitoring of emotional consequences												■														
6. Comparison of behaviour																										
6.1. Demonstration of the behavior		■	■	■								■	■	■	■	■	■	■		■				■	■	
6.2. Social comparison	■																									
7. Associations																										
7.1. Prompts/cues	■																									
8. Repetition and substitution																										
8.1. Behavioral practice/rehearsal		■	■	■								■	■	■	■	■	■	■		■				■		
8.2. Behavior substitution			■	■		■	■	■																		■
8.4. Habit reversal			■	■		■		■																		■
8.6. Generalisation of target behavior														■	■					■						
8.7. Graded tasks	■		■							■		■		■	■	■						■				
9. Comparison of outcomes																										
9.2. Pros and cons				■									■										■			
10. Reward and threat																										
10.3. Non-specific reward	■																									
10.4. Social reward		■																								
10.10. Reward (outcome)		■																								
11. Regulation																										
11.2. Reduce negative emotions		■																								
11.3. Conserving mental resources		■																								
12. Antecedents																										
12.5. Adding objects to the environment		■								■				■			■			■						
15. Self-belief																										
15.1. Verbal persuasion about capability																							■			
15.3. Focus on past success	■																									
Number of BCTs	**20**	**18**	**12**	**9**	**7**	**6**	**4**	**4**	**4**	**2**	**2**	**14**	**11**	**9**	**7**	**6**	**6**	**4**	**2**	**9**	**7**	**7**	**7**	**6**	**4**	**4**

Table 3. Cross matrix of intervention functions and lifestyle behaviour change trials

		Intervention functions						
Studies	**Type of intervention**	**Education**	**Enablement**	**Training**	**Persuasion**	**Environmental restructuring**	**Modelling**	**Incentivisation**
Campbell (2008)	**Diet**	■	■					
Clark (2018)			■			■		
De Brito-Ashurst (2013)		■		■				
Dussol (2005)		■	■					
MDRD Study (1995)		■	■	■	■	■	■	■
Mekki (2010)		■						
Meuleman (2016)		■	■					■
Paes-Barreto (2013)		■			■		■	
Pisani et al (2016)		■						
Rosman (1989)		■	■					
Saran (2017)		■	■					
Aoike et al (2015)	**Physical Activity**	■	■	■				
Barcellos (2018)			■	■				
Greenwood (2015)			■	■		■		
Kao et al (2012)		■	■	■	■			
Leehey (2016)				■				
Rossi et al (2014)		■		■				
Tang (2017)		■	■	■				
Van Craenenbroeck (2015)				■				
Flesher et al (2011)	**Lifestyle**	■	■	■				
Howden et al (2013)		■	■	■		■		
Ishani (2016)		■	■					
Jiamjariyapon (2017)		■	■					
Joboshi (2017)		■	■					
Patil (2013)		■						
Teng et al (2013)		■	■		■			
Total		**21**	**18**	**12**	**4**	**4**	**2**	**2**

Table 4. Effects of the behaviour change interventions on the primary outcome(s)

Study	Primary outcome/s	Measures	Intervention (n)	Control (n)	Intervention[a]	Control[a]	Mean difference (95% CI)	*p*
Dietary interventions								
Campbell (2008)	Body composition	Body cell mass, %	29	27	2.0 (1.9 to 5.9)[b]	1.5 (5.5 to 2.5)[b]	3.5 (2.1 to 9.1)	0.2
		Body cell mass, kg			0.5 (1.8 to 0.8)[b]	0.5 (0.7 to 1.8)[b]	1.1 (0.7 to 2.9)	0.2
Clark (2018)	Change in eGFR	Change eGFR, mL/min/1.73m^2	311	308	−2.2 (−3.3 to −1.1)[b]	−1.9 (−2.9 to −0.9)[b]	−0.3 (−1.8 to 1.2)	0.74
De Brito-Ashurst (2013)	Change in BP	Reduction systolic/diastolic BP	25	23	-	-	-8mmHg (-11 to -5) / 2(-4 to-2)	<0.001
Dussol (2005)	Decrease in eGFR	Decrease eGFR, mL/min/1.73m^2	25	22	-7±11	-5±15	-	-
	24-hour albumin excretion rate	Microalbuminuria, mg/d			+114±364	+156±486	-	-
MDRD[c] Study 1 (1995)	Dietary satisfaction (Study A: GFR 25-55ml/min. 1.73m2)	Dietary satisfaction score	220	221	3.6 ±1.0	3.8 ±1.0	-	<0.05
	Dietary satisfaction (Study B: GFR 13-24ml/min. 1.73m2	Dietary satisfaction score	65	59	3.1 ±0.9	3.6 ±0.9	-	<0.01
MDRD[c] Study 2 (1996)	Decline eGFR (Study A: GFR 25-55ml/min. 1.73m2)	Decline eGFR, baseline to 3 years	291	394	-	-	3.8 (4.2)[d]	-
	Decline eGFR (Study B: GFR 13-24ml/min. 1.73m2)	Decline eGFR, baseline to 3 years	126	129	-	-	4.0 (3.1)[d]	-
Mekki (2010)	Total cholesterol (TC)	TC/mmol L-1	20	20	4.1±0.5	5.4±0.4	-	<0.05
	Triacylglycerols (TG)	TG/mmol L-1			2.9±0.1	3.9 ±0.1	-	<0.05
Meuleman (2016)	Blood pressure	Office systolic BP, mmHg	67	71	-	-	-7.3 (-12.7 to -1.9)[e]	<0.01
		Office diastolic BP, mmHg			-	-	-3.8 (-6.9 to -0.6)[i]	<0.05
	Sodium excretion	Sodium excretion rate, mmol/24h			-	-	2.9 (-21.6 to 27.3)[i]	
Paes-Barreto (2013)	Change in protein intake	Change protein intake, g/day	43	46	-20.7 (-30.9%)[f]	-10.5 (-15.1%)[e]	-	0.04
Pisani (2016)	Protein intake	Change protein intake, g/kg/day	27	27	-0.1 (-0.17 to -0.03)[b]	-0.2 (-0.28 to -0.13)[b]	-	0.04
	UUN excretion	Change UUN, g/day			-1.3 (-2.1 to -0.5)[b]	-2.8 (-3.6 to -2)[b]	-	0.008
	SUN	Change SUN, mg/dL			2.96 (-7.71 to13.64)[b]	-16.63 (-27.3 to -5.96)[b]	-	0.012
	Urinary phosphate excretion	Change phosphate excretion, mg/day			-27.6 (-93.7 to 38.4)[b]	-165.3 (-231.3 to -99.2)[b]	-	0.005
	Serum phosphate concentration	Change serum phosphate, mg/dL			0.2 (0 to 0.4)[b]	-0.1 (-0.3 to 0.2)[b]	-	0.093
	Adherence	Met criteria, n, %			19 (70%)[g]	11 (44%)[f]	-	-
Rosman (1989)	Adherence (Group A1 & B: CrCl >30)	Median 24 hr urea excretion mmol/24 hr	45	47	-	-	-	<0.01
	Adherence (Group A2 & C: CrCl≤30)	Median 24 hr urea excretion mmol/24 hr	23	17	-	-	-	<0.01
Saran (2017)	Change hydration status	Extracellular Volume, L	29	29	-	-	-1.02 (-1.48 to 0.56)[h]	<0.001
		Intracellular Volume, L			-	-	-0.06 (-0.12 to 0.01)[g]	0.02
Physical activity interventions								
Aoike (2015)	Cardiopulmonary	Maximal ventilation, L/min	14	15	90.7 ± 28.1	76.6 ± 23.3	-	0.003
	parameters	Ventilatory threshold,			26.1 ± 7.0	24.2 ± 7.1	-	0.302

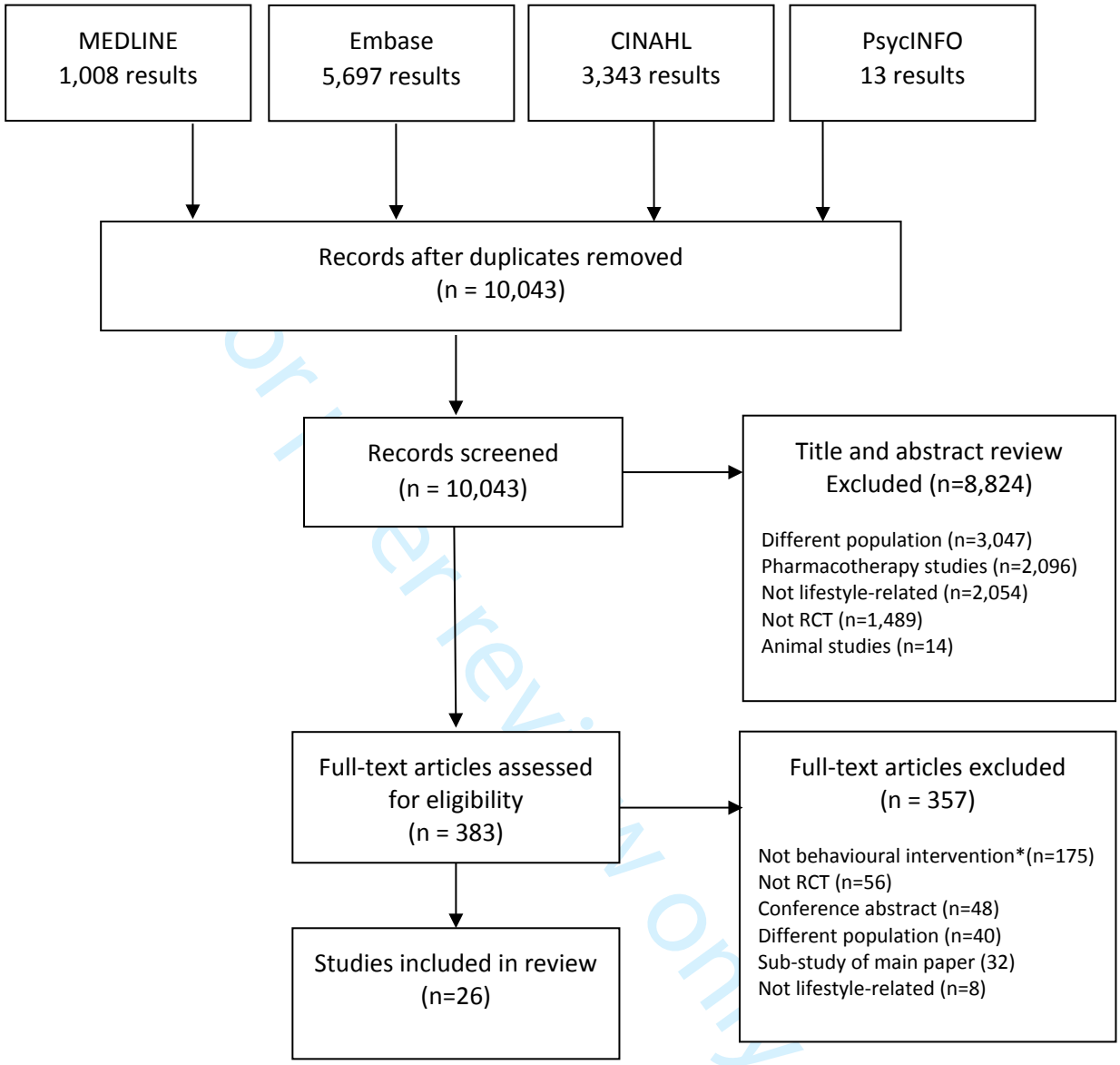
Study	Primary outcome/s	Measures	Intervention (n)	Control (n)	Intervention[a]	Control[a]	Mean difference (95% CI)	*p*
		VO_2peak, Ml/kg/min						
		VO_2 in respiratory compensation point, Ml/kg/min			21.7 ± 5.5	19.0 ± 5.6	-	0.073
		Speed in respiratory compensation point, Km/h			6.8 ± 1.1	5.8 ± 1.0	-	<0.001
	Functional capacity	6MWT, minutes			583.1 ± 85.2	561.2 ± 91.2	-	0.028
		Time up /go test, seconds			5.82 ± 1.39	6.42 ± 1.11	-	0.001
		Arm curl test, repetitions			22.8 ± 4.8	18.1 ± 3.1	-	<0.001
		STST, repetitions			24.0 ± 7.1	18.3 ± 4.8	-	<0.001
		2-min step test, steps			219.3 ± 36.7	179.9 ± 36.3	-	<0.001
		Back scratch test, cm			6.4 ± 6.6	12.6 ± 9.9	-	0.05
	Systolic & diastolic BP	Systolic BP, mmHg			118.7 ± 7.3	126.8 ± 6.7	-	0.012
		Diastolic BP, mmHgP			76.1 ± 4.4	81.0 ± 3.7	-	0.038
	Renal function	Serum creatinine, mg/dL			2.6 ± 1.1	3.2 ± 1.4	-	0.215
		eGFR, mL/min/1.73m^2			31.9 ± 13.7	23.9 ± 12.2	-	0.046
Barcellos (2018)	Mean change in eGFR	Change eGFR, mL/min/1.73m^2	76	74	61.5 (57.0 to 66.1)[b]	59.0 (54.2 to 63.8)[b]	0.7 (-4.0 to 5.4)	-
Greenwood (2015)	Mean change in eGFR	Change eGFR, mL/min/1.73m^2	8	10	-3.8±2.8	-8.5±6.4	7.8±3.0 (1.1 to 13.5)	0.02
Kao (2012)	Depression	Change depression (Beck Depression Inventory-II scale)	45	49	-3.71[i]	1.33[h]	-	<0.01
	Fatigue	Change fatigue			-4.74[h]	1.91[h]	-	<0.001
	Exercise behaviour	Change weekly exercise			4.28[h]	-1.24[h]	-	<0.001
Leehey (2016)	UPCR ratio	UPCR (mg/g) at 52 wks	14	18	405 (225 to 1038)[j]	618 (323 to 1155)[j]	-	0.39
Rossi (2014)	Physical function	6MWT, minutes	59	48	210.4±266	-10±219.9	-	<0.001
		STST, seconds			26.9±27% age prediction[k]	0.7±12.1% age prediction[j]	-	<0.001
		Gait speed, cm			9.5 (-36.4 to 34)[j]	0 (-9 to 13)[j]	-	0.76
	QoL (RAND SF-36),	Role functioning/physical			19.0 ±31.7	-8.9 ±38.4	-	<0.001
	mean change from	Physical functioning			11.1±19.3	-0.7 ±18.7	-	0.004
	baseline	Energy/fatigue			9.8 ±17.6	0.5 ±18.0	-	0.01
		General health			4.9 ±15.3	-1.2 ±11.5	-	0.03
		Pain			5.7 ±20.0	-3.8 ±24.4	-	0.04
		Emotional wellbeing			4.2 ±16.9	-0.4 ±17.1	-	0.2
		Social functioning			4.2 ±20.8	1.6 ±22.6	-	0.57
		Role functioning/emotional			6.9 ±24.5	1.9 ±29.2	-	0.38
Tang (2017)	Physical function	Change 6MWT, minutes	42	42	41.93 ±14.57	-5.05 ±14.81	-	<0.001
		Change STST, seconds			-2.68 ±1.95	0.49 ±2.07	-	<0.001
	Self-efficacy	Change self-efficacy score			6.64 ±6.92	-3.72 ±6.80	-	<0.001
	Anxiety	Change HAD-A score			-1.02±1.47	0.21 ±2.17	-	0.003
	Depression	Change HAD-D score			-0.76 ±1.32	0.31±1.84	-	0.003
	QoL (KDQOL-SF),	Symptom/problem list			2.49 ±4.81	0.38 ±6.97	-	0.007
	mean change from	Effects of kidney disease			1.90 ±5.22	−1.56 ±9.64	-	0.005
	baseline	Burden of kidney disease			−0.45 ±15.27	−15.3 ±18.11	-	<0.001
		SF-12 PCS			1.08 ±3.60	−0.74 ±4.55	-	0.045

Study	Primary outcome/s	Measures	Intervention (n)	Control (n)	Intervention[a]	Control[a]	Mean difference (95% CI)	*p*
		SF-12 MCS			1.87 ±5.69	−0.73 ±4.53	-	0.002
Van Craenenbroeck (2015)	Peripheral endothelial function	Flow mediated dilation of brachial artery	19	21	4.6 ±3.0	5.3 ± 3.1	0.32 (-1.88 to 2.53)	0.9
Lifestyle interventions								
Flesher (2011)	Composite of eGFR, TC, US, UP, BP	Number of improved endpoints	23	17	83	30		0.028
Howden (2013)	Change in CRF	VO_2, ml/kg per minute	36	36	2.8±0.7	0.3±0.9	-	0.004
Ishani (2016)	Composite death, hospitalization, emergency visits, admission nursing facility	Occurrence of primary outcome/hazard ratio	451	150	208 (46.2%)	70 (46.7%)	-	0.9
Jiamjariyapon (2017)	Mean change in eGFR	Change eGFR, mL/min/1.73m^2	234	208	42.4 ±1.5	39.9 ±2.8	2.74 (0.60-4.50)	0.009
Joboshi (2017)	Perceived behaviour	Self-efficacy	32	29	r=0.27, U=318.5[l]	-	-	0.035
		Self-management			r=0.27, U=310.0[k]	-	-	0.026
Patil (2013)	24-hr urine protein	24-hr urine protein, g/d	23 (B)	22 (A),31 (C)	1284.74 ± 1079.94	A: 1079.27 ±1269.20; C: 1187.61±756.92	-	-
	BMI	Change in BMI (paired t-test)			-1.95 ±1.10	A: -0.15 ±0.38 (p=0.069); C: -2.56 ±0.68 (p=0.000)	-	0.000
Teng (2013)	Health-promotion lifestyle behaviours (HPLP-IIC)	Stress management	45	45	-	-	2.76	0.10
		Interpersonal relations			-	-	3.88	0.05
		Health responsibility			-	-	13.63	0.001
		Physical activity			-	-	7.50	0.01
		Spiritual growth			-	-	2.79	0.10
		Nutrition			-	-	2.62	0.11
	Renal function protection knowledge	Knowledge renal function, Chinese herbs & CKD diet			-	-	No data	0.001
	Physical function	6MWT, minutes	45	45	420.4 ±81.2	368.5 ±99.7	-	0.04

Abbreviations: CI, Confidence interval; eGFR, estimated glomerular filtration rate; BP, blood pressure; UUN, urinary urea nitrogen; SUN, Serum urea nitrogen; 6MWT, 6 Minute Walk Test; STST, Sit to Stand Test; UPCR, Urine protein to creatinine ratio; QoL, Quality of life; RAND SF-36, 36-Item Short Form Survey; HAD-A/HAD-D, Hospital Anxiety & Depression Scale; KDQOL-SF, Kidney Disease & Quality of Life Short Form; SF-12 PCS/MCS, Physical and Mental Health Composite Scores; TC, Total cholesterol; US, Urinary sodium; UP, Urinary protein; CRF, Cardiorespiratory fitness; BMI, Body Mass Index; HPLP-IIC, Health Promoting Lifestyle Profile-II Chinese version (questionnaire)

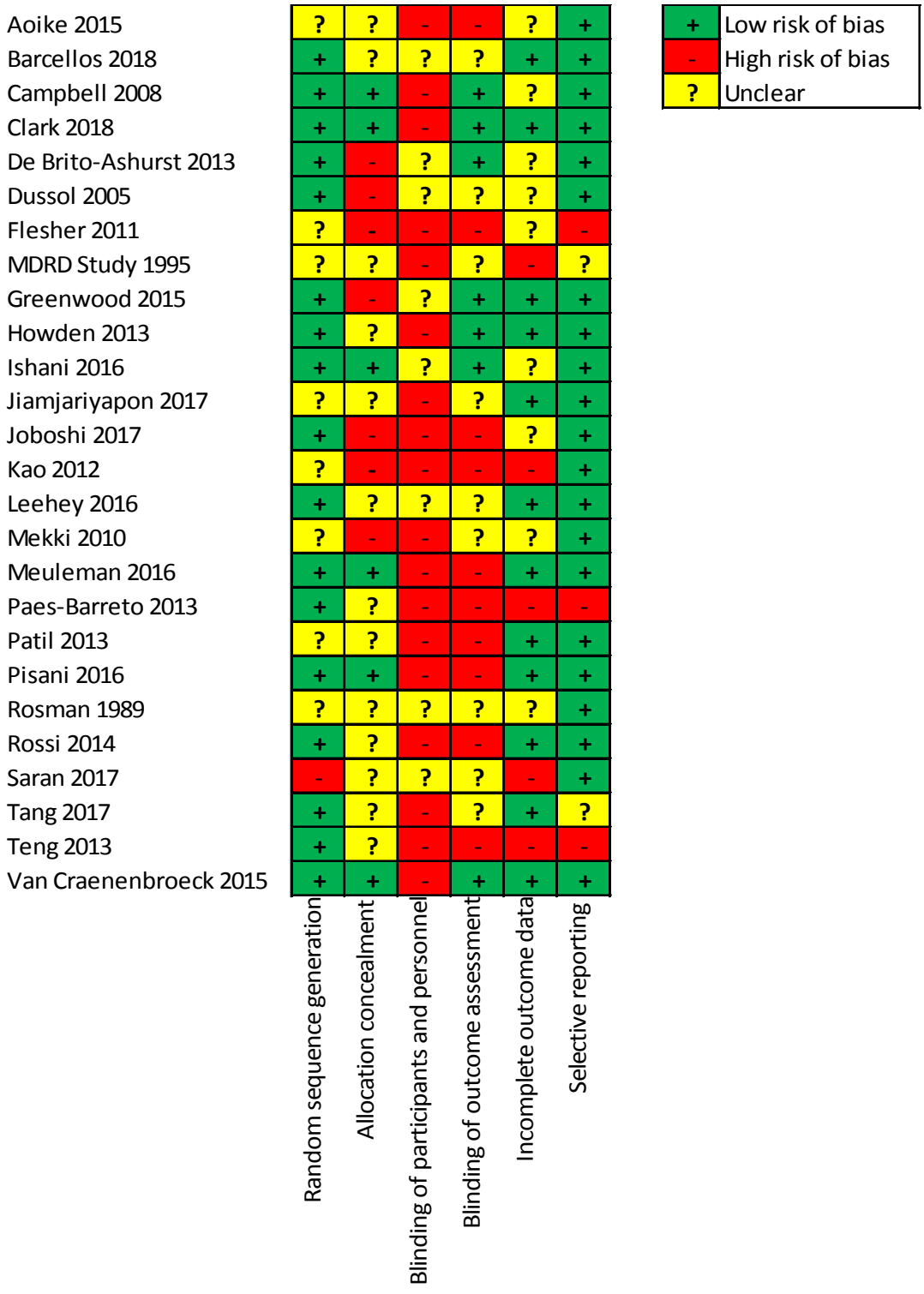
[a] Unless otherwise indicated, values are shown as mean+/-SD
[b] Mean change (95% confidence interval)
[c] Modification of Diet in Renal Disease (MDRD) study (Gillis et al (1995), Coyne et al (1995))
[d] Mean decline +/- SD
[e] Mean change from baseline after 6 months
[f] Mean change and % reduction from baseline values
[g] Number of participants who met adherence criteria (n,%)
[h] p-value calculated as p<0.05 x group interaction (Aoike 2015)
[i] Paired T test
[j] Median (IQR)
[k] STST results standardized as a percentage of age-predicted value using prediction formulas (Rossi 2014)
[l] Effect size (r) Median, Mann-Whitney's U Test

Figure 1. PRISMA flowchart of included/excluded studies



*A behavioural intervention explicitly describes a behaviour change technique which can be coded using the Behaviour Change Technique Taxonomy version 1

Figure 2. Risk of bias for individual studies (n=26)



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2, 3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3, 6
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6, 7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	7, FileS2
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6, 7, 34
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7, 9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	12
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	12, 13

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	n/a
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	n/a
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	9
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	9, 25-27
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	9
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	12, 13, 30-32
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	n/a
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	9, 34
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	n/a
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13-15
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	16
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	18

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

File S2. Search strategies

Search results: MEDLINE via OvidSP (1946 to 20 September 2018)

#	Search terms	Results
1	exp Renal Insufficiency/	152,141
2	exp Renal Insufficiency, Chronic/	101,640
3	Kidney diseases/	79,478
4	(chronic kidney or chronic renal).tw.	59,047
5	(CKD or CRD).tw.	19,371
6	(predialysis or pre-dialysis).tw.	4,177
7	1 or 2 or 3 or 4 or 5 or 6	243,965
8	exp health behaviour/	163,935
9	exp habits/	34,134
10	lifestyle$.tw.	66,158
11	exp Health promotion/	67,019
12	exp Health education/	155,589
13	exp Diet/	240,468
14	exp Diet Therapy/	48,800
15	exp Food Habits/	33,822
16	Fruit/ and Vegetables/	9,462
17	((diet or diets or dietary) adj5 (Mediterranean or vegetarian or plant-based or American Heart Association* or DASH or western or seafood)).tw.	9,130
18	((diet or dietary or nutrition*) adj (survey* or record or records or score)).tw.	6,572
19	exp Exercise/	160,256
20	exp Exercise therapy/	42,215
21	exp Exercise movement techniques/	6,911
22	aerobic exercise/	90,067
23	exp Smoking/	140,996
24	exp Smoking cessation/	25,651
25	exp Drinking behaviour/	68,788
26	exp Alcoholism/	72,211
27	exp Alcoholic intoxication/	12,043
28	exp Binge drinking/	1,195
29	8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28	1,027,712
30	randomized controlled trial.pt.	466,609
31	pragmatic clinical trial.pt.	761
32	controlled clinical trial.pt.	92,933
33	randomized.ab.	354,404
34	placebo.ab.	174,060
35	clinical trials as topic.sh.	180,151
36	randomly.ab.	243,654
37	trial.ti.	160,708
38	30 or 31 or 32 or 33 or 34 or 35 or 36 or 37	1,034,856
39	7 and 29 and 38	1,008

Search results: Embase via OvidSP (1996 to 20 September 2018)

#	Search terms	Results
1	exp chronic kidney disease/	62,294
2	exp kidney disease/	849,346
3	(chronic kidney or chronic renal).tw.	92,692
4	(CKD or CRD).tw.	37,030
5	(predialysis or pre-dialysis).tw.	6,221
6	1 or 2 or 3 or 4 or 5	863,647
7	exp health behaviour/	349,149
8	exp habit	28,571
9	exp lifestyle	113,466
10	exp lifestyle modification	30,765
11	exp sedentary lifestyle	9,819
12	lifestyle$.tw.	100,473
13	exp health promotion/	85,281
14	exp health education/	285,678
15	exp diet	324,233
16	exp diet therapy	333,497
17	exp feeding behaviour	160,127
18	exp renal diet	92
19	Fruit/ and Vegetables/	20,205
20	((diet or diets or dietary) adj5 (Mediterranean or vegetarian or plant-based or American Heart Association* or DASH or western or seafood)).tw.	14,599
21	((diet or dietary or nutrition*) adj (survey* or record or records or score)).tw.	8,893
22	exp exercise	312,543
23	exp physical activity	370,197
24	exp smoking	312,045
25	exp smoking cessation	50,560
26	exp smoking habit	22,226
27	exp smoking cessation program	3,316
28	exp drinking behaviour	45,218
29	exp drinking pattern	45,218
30	exp binge drinking	3,432
31	exp alcohol consumption	113,850
32	exp alcohol abuse	37,477
33	exp alcohol abstinence	5,831
34	exp alcohol intoxication	12,743
35	exp alcoholism	119,763
36	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35	2,186,119
37	randomized.ab.	540,955
38	placebo.ab.	249,626
39	randomly.ab.	354,161
40	trial.ti.	236,549
41	37 or 38 or 39 or 40	1,068,038
44	6 and 36 and 41	5,679

Search results: CINAHL via EBSCO (1982 to 20 September 2018)

#	Search terms	Results
S21	S3 AND S20	3,343
S20	S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19	440,706
S19	(MH "Alcohol Drinking+")	14,329
S18	(MH "Alcoholic Intoxication+")	1,759
S17	(MH "Alcoholism") OR (MH "Alcoholic Intoxication+")	10,496
S16	(MH "Drinking Behaviour+")	16,090
S15	(MH "Smoking+")	39,165
S14	(MH "Aerobic Exercises+")	24,457
S13	(MH "Therapeutic Exercise+")	32,306
S12	(MH "Exercise+")	62,514
S11	"fruit and vegetables"	736
S10	(MH "Diet Therapy+")	15,217
S9	(MH "Diet+")	58,812
S8	(MH "Health Education+")	83,615
S7	(MH "Health Promotion+")	37,813
S6	(MH "Life Style+")	124,973
S5	(MH "Habits+")	45,961
S4	(MH "Health Behaviour+")	57,214
S3	S1 OR S2	33,991
S2	MH "kidney diseases+"	33,991
S1	(MH "Renal Insufficiency+") OR (MH "Renal Insufficiency, Chronic+")	17,914

PsycINFO via OvidSP (1806 to 20 September 2018)

#	Search terms	Results
1	exp Kidney Diseases/	1,983
2	(chronic kidney or chronic renal).tw.	1,148
3	(predialysis or pre-dialysis).tw.	70
4	(CKD or CRD).tw.	476
5	1 or 2 or 3 or 4	2,613
6	exp Health Behaviour/	26,049
7	exp HABITS/	33,531
8	exp Eating Behaviour/	18,434
9	exp LIFESTYLE/	10,664
10	exp Lifestyle Changes/	1,163
11	exp Health Promotion/	22,016
12	exp Health Education/	17,199
13	exp Behaviour Change/	11,102
14	exp DIETS/	11,487
15	exp Food Preferences/	4,394
16	"fruit and vegetable*".tw.	2,354
17	((diet or diets or dietary) adj5 (Mediterranean or vegetarian or plant-based or American Heart Association* or DASH or western or seafood)).tw.	706
18	((diet or dietary or nutrition*) adj (survey* or record or records or score)).tw.	582
19	exp Physical Activity/	35,706
20	exp Exercise/	23,406
21	aerobic exercise/	1,557
22	exp SMOKING CESSATION/	12,102
23	exp TOBACCO SMOKING/	29,024
24	exp Drinking behaviour/	68,488
25	exp Alcohol Drinking Patterns/	63,023
26	exp ALCOHOLISM/	29,297
27	exp Binge Drinking/	2,069
28	exp Alcohol Abuse/	45,860
29	exp Alcohol Intoxication/	3,046
30	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29	228,162
31	randomized.ab.	57,824
32	placebo.ab.	36,556
33	randomly.ab.	65,494
34	trial.ti.	26,290
35	31 or 32 or 33 or 34	149,264
36	5 and 30 and 35	13

Table S1. Behaviour Change Technique Taxonomy (v1)

Grouping and BCTs	Grouping and BCTs	Grouping and BCTs
1. Goals and planning	**6. Comparison of behaviour**	**12. Antecedents**
1.1. Goal setting (behavior)	6.1. Demonstration of the behavior	12.1. Restructuring the physical environment
1.2. Problem solving	6.2. Social comparison	12.2. Restructuring the social environment
1.3. Goal setting (outcome)	6.3. Information about others' approval	12.3. Avoidance/reducing exposure to cues for the behavior
1.4. Action planning	**7. Associations**	12.4. Distraction
1.5. Review behavior goal(s)	7.1. Prompts/cues	12.5. Adding objects to the environment
1.6. Discrepancy between current behavior and goal	7.2. Cue signalling reward	12.6. Body changes
1.7. Review outcome goal(s)	7.3. Reduce prompts/cues	**13. Identity**
1.8. Behavioral contract	7.4. Remove access to the reward	13.1. Identification of self as role model
1.9. Commitment	7.5. Remove aversive stimulus	13.2. Framing/reframing
2. Feedback and monitoring	7.6. Satiation	13.3. Incompatible beliefs
2.1. Monitoring of behavior by others without feedback	7.7. Exposure	13.4. Valued self-identify
2.2. Feedback on behaviour	7.8. Associative learning	13.5. Identity associated with changed behavior
2.3. Self-monitoring of behaviour	**8. Repetition and substitution**	**14. Scheduled consequences**
2.4. Self-monitoring of outcome(s) of behaviour	8.1. Behavioral practice/rehearsal	14.1. Behavior cost
2.5. Monitoring of outcome(s) of behavior without feedback	8.2. Behavior substitution	14.2. Punishment
2.6. Biofeedback	8.3. Habit formation	14.3. Remove reward
2.7. Feedback on outcome(s) of behavior	8.4. Habit reversal	14.4. Reward approximation
3. Social support	8.5. Overcorrection	14.5. Rewarding completion
3.1. Social support (unspecified)	8.6. Generalisation of target behavior	14.6. Situation-specific reward
3.2. Social support (practical)	8.7. Graded tasks	14.7. Reward incompatible behavior
3.3. Social support (emotional)	**9. Comparison of outcomes**	14.8. Reward alternative behavior
4. Shaping knowledge	9.1. Credible source	14.9. Reduce reward frequency
4.1. Instruction on how to perform the behavior	9.2. Pros and cons	14.10. Remove punishment
4.2. Information about Antecedents	9.3. Comparative imagining of future outcomes	**15. Self-belief**
4.3. Re-attribution	**10. Reward and threat**	15.1. Verbal persuasion about capability
4.4. Behavioral experiments	10.1. Material incentive (behavior)	15.2. Mental rehearsal of successful performance
5. Natural consequences	10.2. Material reward (behavior)	15.3. Focus on past success
5.1. Information about health consequences	10.3. Non-specific reward	15.4. Self-talk
5.2. Salience of consequences	10.4. Social reward	**16. Covert learning**
5.3. Information about social and environmental consequences	10.5. Social incentive	16.1. Imaginary punishment
5.4. Monitoring of emotional consequences	10.6. Non-specific incentive	16.2. Imaginary reward
5.5. Anticipated regret	10.7. Self-incentive	16.3. Vicarious consequences
5.6. Information about emotional consequences	10.8. Incentive (outcome)	
	10.9. Self-reward	
	10.10. Reward (outcome)	
	10.11. Future punishment	
	11. Regulation	
	11.1. Pharmacological support	
	11.2. Reduce negative emotions	
	11.3. Conserving mental resources	
	11.4. Paradoxical instructions	

Available as a public resource from the Behaviour Change Technique Taxonomy Online Training website:

http://www.bct-taxonomy.com/

Supplementary Table S2. Characteristics of lifestyle behavior change interventions

	Total trials (n=26)	Dietary (n=11)	Physical activity (n=8)	Lifestyle[1] (n=7)
Characteristic				
Setting[2]				
Individual	**9**	6	1	2
Combination individual and group	**7**	1	4	2
Group	**2**	1	0	1
Not specified	**7**	3	2	2
Delivery				
Face-to-face with telephone follow-up	**14**	7	6	1
Face-to-face	**7**	3	1	3
Online	**1**	0	0	1
Not specified	**3**	1	0	2
Location[2]				
Hospital/clinic	**10**	7	1	2
Home	**8**	1	4	3
Gym	**3**	0	1	2
Other[3]	**3**	1	2	0
Not specified	**6**	3	1	2
Total intervention duration				
1 month	**1**	1	0	0
3 months	**10**	3	6	1
4 to 6 months	**6**	3	1	2
12 months	**5**	1	1	3
24 to 36 months	**4**	3	0	1
Facilitator/ educator[2]				
Dietician	**12**	8	0	4
Nurse	**6**	0	1	5
Exercise physiologist/ physiotherapist	**4**	0	2	2
Psychologist	**3**	1	0	2
Social worker	**2**	0	0	2
Nephrologist	**2**	1	0	1
Researcher	**2**	2	0	0
General practitioner/medical doctor	**1**	0	1	0

[1] Any combination of diet, physical activity, weight reduction or smoking cessation
[2] Many interventions use multiple settings, locations and facilitators, therefore numbers overlap
[3] Community, physical therapy or cardiac rehabilitation centers, university premises

Volunteers/peers	**1**	1	0	0
Other[4]	**5**	0	3	2
Not specified	**4**	2	2	0
Number of facilitators				
Single	**12**	7	3	2
Multiple	**8**	2	2	4
Not specified	**6**	2	3	1
Informed by theory				
Yes	**5**	2	2	1
No	**21**	9	6	6

[4] Clinical pharmacy specialist, health educator, physical education professional, community network officer

Supplemental Table S3. Characteristics of interventions with improved outcomes

	Education	Enablement	Training	Persuasion	Environmental restructuring	Modelling	Incentivisation	Total functions
Studies with an improvement in at least one primary outcome (n=18)								
Meuleman (2016)	•	•					•	**3**
De Brito-Ashurst (2013)	•		•					**2**
MDRD Study (1995)	•	•	•	•	•	•	•	**7**
Mekki (2010)	•							**1**
Paes-Barreto (2013)	•			•		•		**3**
Pisani et al (2016)	•							**1**
Rosman (1990)	•	•						**2**
Saran (2017)	•	•						**2**
Patil (2013)	•							**1**
Flesher et al (2011)	•	•	•					**3**
Howden et al (2013)	•	•	•		•			**4**
Jiamjariyapon (2017)	•	•						**2**
Joboshi (2017)	•	•						**2**
Teng et al (2013)	•	•		•				**3**
Aoike et al (2015)	•	•	•					**3**
Kao et al (2012)	•	•	•	•				**4**
Rossi et al (2014)	•		•					**2**
Tang (2017)	•	•	•					**3**
Total studies (n,%)	**18 (100%)**	**12 (67%)**	**8 (44%)**	**4 (22%)**	**2 (11%)**	**2 (11%)**	**2 (11%)**	
Studies with no improvements in primary outcomes (n=8)								
Campbell et al (2008)	•	•						**2**
Clark (2018)		•			•			**2**
Dussol (2005)	•	•						**2**
Ishani (2016)	•	•						**2**
Greenwood (2015)		•	•		•			**3**
Barcellos (2018)		•	•					**2**
Leehey (2016)			•					**1**
Van Craenenbroeck (2015)			•					**1**
Total functions (n,%)	**3 (38%)**	**6 (75%)**	**4 (50%)**	**0**	**2 (25%)**	**0**	**0**	

BMJ Open

Lifestyle behaviour change for preventing the progression of chronic kidney disease: a systematic review

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Manuscript ID	bmjopen-2019-031625.R1
Article Type:	Original research
Date Submitted by the Author:	15-Aug-2019
Complete List of Authors:	Evangelidis, Nicole; The University of Sydney School of Public Health; Children's Hospital at Westmead, Centre for Kidney Research Craig, Jonathan; Flinders University Faculty of Medicine Nursing and Health Sciences, College of Medicine and Public Health, ; Children's Hospital at Westmead, Centre for Kidney Research Bauman, Adrian; University of Sydney, School of Public Health Manera , Karine; The University of Sydney School of Public Health; Children's Hospital at Westmead, Centre for Kidney Research Saglimbene, Valeria; The University of Sydney School of Public Health; Children's Hospital at Westmead, Centre for Kidney Research Tong, Allison; The University of Sydney, Sydney School of Public Health; Children's Hospital at Westmead, Centre for Kidney Research
Primary Subject Heading:	Public health
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	Chronic kidney disease, Diet, Exercise, Behaviour change techniques, Lifestyle

Lifestyle behaviour change for preventing the progression of chronic kidney disease: a systematic review

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ABSTRACT

Objectives: Modifying lifestyle can prevent the progression of chronic kidney disease (CKD) but the specific elements which lead to favourable behaviour change are not well understood. We aimed to identify and evaluate behaviour change techniques and functions in lifestyle interventions for preventing the progression of CKD.

Design: Systematic review.

Data sources: MEDLINE, EMBASE, CINAHL and PsycINFO.

Eligibility criteria: Trials of lifestyle behaviour change interventions (including diet, physical activity, smoking and/or alcohol) published to September 2018 in adults with CKD stages 1-5.

Data extraction and synthesis: Trial characteristics including population, sample size, study setting, intervention, comparator, outcomes and study duration, were extracted. Study quality was independently assessed by two reviewers using the Cochrane risk of bias tool. The Behaviour Change Technique Taxonomy v1 was used to identify behaviour change techniques (e.g. goal setting) and the Health Behaviour Change Wheel was used to identify intervention functions (e.g. education). Both were independently assessed by three reviewers.

Results: In total, 26 studies involving 4,263 participants were included. Risk of bias was high or unclear in most studies. Interventions involved diet (11), physical activity (8) or general lifestyle (7). Education was the most frequently used function (21 interventions), followed by enablement (18), training (12), persuasion (4), environmental restructuring (4), modelling (2) and incentivisation (2). The most common behaviour change techniques were behavioural instruction

(23 interventions), social support (16), behavioural demonstration (13), feedback on behaviour (12) and behavioural practice/rehearsal (12). Eighteen studies (69%) showed a significant improvement in at least one primary outcome, all of which included education, persuasion, modelling and incentivisation.

Conclusion: Lifestyle behaviour change interventions for CKD patients frequently used education, goal setting, feedback, monitoring and social support. The most promising interventions included education and used a variety of intervention functions (persuasion, modelling and incentivisation).

Keywords: chronic kidney disease (CKD), lifestyle, diet, exercise, behaviour change techniques, Health Behaviour Change Wheel, Behaviour Change Technique Taxonomy v1, systematic review.

ARTICLE SUMMARY

Strengths and limitations of this study

- We used comprehensive, evidence-based frameworks to identify and describe behaviour change techniques and intervention functions in lifestyle behavioural interventions for patients with CKD.
- Coding of behaviour change techniques and intervention functions was systematically and independently conducted by three researchers, and risk of bias was assessed.
- Summary estimates could not be ascertained due to the heterogeneity of interventions and outcome measures.

Funding statement

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Competing interests statement

The authors do not have any competing interests or conflicts of interest to declare.

PROSPERO registration number: CRD42019106053

INTRODUCTION

Preventing the progression of CKD is a high priority for patients and clinicians, to reduce the requirement for dialysis.[1-3] Lifestyle interventions which modify behavioural risk factors such as poor diet and low physical activity can prevent progression of CKD and life-threatening complications and improve quality of life and survival.[4-6] Addressing behaviour change is particularly relevant in CKD as lifestyle modification can be challenging. Poor adherence to diet, medication and other treatments is common in CKD.[7] Barriers to modifying lifestyle include low health literacy, conflicts with cultural norms, complicated nutritional requirements and safety concerns.[7-11]

Guidelines recommend the explicit use of behaviour change for addressing lifestyle risk factors when designing and reporting interventions for patients with CKD.[12,13] However, it is uncertain which aspects of lifestyle behaviour change interventions are the most effective, and reporting of behavioural components is often unclear, making implementation in practice problematic.

The Behaviour Change Technique Taxonomy v1 was developed to provide a comprehensive framework that integrates behaviour change techniques used in interventions.[14] The Taxonomy was further synthesized into a framework, the Health Behaviour Change Wheel which describes the intervention functions necessary to change health behaviors.[15] The Health Behaviour Change Wheel provides a broad, overarching framework in which to characterize behaviour change interventions while the Taxonomy identifies specific techniques related to individual behaviours. The intervention functions described in the Health Behaviour Change Wheel can be delivered by a variety of behaviour change techniques. For example, the intervention function, “education”, outlined in the Wheel, can include the behaviour change techniques “instruction on how to perform the behaviour” and “information about antecedents”, detailed in the Taxonomy. Similarly, the

intervention function "incentivisation" can incorporate techniques such as "feedback on behaviour" and "rewards".

Behaviour change interventions using the Wheel and the Taxonomy can effectively change lifestyle behaviours. For example, a text-messaging and pedometer program improved physical activity in people at high risk of type 2 diabetes[16], a digital healthy eating program increased consumption of fruit and vegetables and sustained this over a 6-month period[17] and a digital behaviour change program achieved significant weight loss results in individuals at risk of type-2 diabetes.[18] The Taxonomy and the Wheel are recommended approaches to modify lifestyle risk factors for chronic disease prevention.[12,16,18] However, these frameworks have not been used in designing and reporting behaviour change strategies in lifestyle interventions for patients with CKD.

We aimed to identify and evaluate behaviour change techniques and intervention functions used in lifestyle interventions for preventing the progression of CKD. This may inform the development of effective and replicable behaviour change interventions for the prevention of CKD, leading to improvements in patient outcomes.

METHODS

The review protocol was registered with the international prospective register of systematic reviews (http://www.crd.york.ac.uk/PROSPERO; registration number CRD42019106053). We used the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Statement[19] and checklist to report this systematic review (Supplementary File S1).

Selection criteria

We included randomized trials of lifestyle behaviour change interventions (including, but not restricted to diet, physical activity, smoking and alcohol consumption) in adult patients (aged over

18 years) with CKD stages 1-5 and not requiring renal replacement therapy. We did not apply restrictions based on outcomes or language. Studies including a combination of pharmacological therapy and lifestyle were included but trials involving only pharmacological therapies were excluded.

Literature search

A comprehensive search was conducted in MEDLINE (1946 to 20 September 2018), Embase (1996 to 20 September 2018), CINAHL (1982 to 20 September 2018) and PsycINFO (1806 to 20 September 2018) using Medical Subject Heading (MeSH) terms relating to CKD, and lifestyle behaviour change interventions (Supplementary File S2), and reference lists of relevant articles and reviews. Author N.E. screened the studies by title and abstract and assessed full-text articles for eligibility. Those that did not meet the inclusion criteria were excluded.

Data extraction and critical appraisal

The trial characteristics relevant to the population, sample size and study setting as well as intervention (type, mode of delivery, use of theory, intervention functions (as described in the Health Behaviour Change Wheel[15]) and behaviour change techniques (as described in the Behaviour Change Technique Taxonomy v1[14])), comparator, outcomes and study duration, were extracted and tabulated. We assessed the risk of bias using the Cochrane tool for randomized studies.[20] N.E. and K.M. assessed the risk of bias in each study independently and any differences were resolved by discussion.

We contacted the authors of the studies when it was necessary to gather additional information. Supplemental data was available in 12 of the 26 studies. In 6 studies with no supplemental data, sufficient information was available in the published article. Therefore, we contacted 8 authors to request further information and received responses from 2 authors.

Analysis of intervention functions and behaviour change techniques

The Behaviour Change Technique Taxonomy v1 (the 'Taxonomy') and Health Behaviour Change Wheel (the 'Wheel') are comprehensive tools for identifying behavioural components in interventions and how frequently they occur.[14,15] The two frameworks are complementary and in addition to designing interventions, they have been used as a method for identifying behavioural components in public health interventions and clinical trials.[21] The tools have been used in previous systematic reviews to identify behaviour change techniques and functions in health interventions.[22-28]

Behaviour change techniques

The Behaviour Change Technique Taxonomy consists of 93 behaviour change techniques, such as goal-setting, self-monitoring, social support and re-structuring the physical environment (see Supplementary Table S1 for the full taxonomy). The techniques are grouped into 16 domains: goals and planning, feedback and monitoring, social support, shaping knowledge, natural consequences, comparison of behaviour, associations, repetition and substitution, comparison of outcomes, reward and threat, regulation, antecedents, identity, scheduled consequences, self-belief and covert learning.

Intervention functions

There are nine intervention functions in the Wheel: education, persuasion, incentivisation, coercion, training, enablement, modelling, environmental restructuring and restrictions.[15] These are activities designed to change behaviours and include one or more behaviour change techniques. Definitions of each intervention function have been described by Michie et al and were used to inform decisions about what functions were present in each study.[15]

Authors N.E. and K.M completed online training for interpreting the Wheel and the Taxonomy to ensure consistency and reliability of coding.[29] N.E., K.M. and V.S. independently read intervention descriptions line-by-line to locate text matching a definition of an intervention function[15] and the description of behaviour change techniques from the BCTTv1 coding frame (Table S1). Each of the 93 behaviour change techniques were indicated as either present or absent in a standardized data extraction form. A behaviour change technique had to be explicitly described to be coded and included in the analysis. The authors compared the codes and discussed discrepancies to reach consensus.

Patient and Public Involvement

No patient involved.

RESULTS

Literature search and study characteristics

The literature search yielded 10,043 citations from which 26 studies (n= 4,263 participants) were eligible and included in the review (Figure 1). Study characteristics are shown in Table 1. The studies were conducted in 15 countries.

Risk of bias assessment

Overall, the reporting of studies was relatively incomplete, particularly for the blinding of participants and personnel which was missing or unclear in every study (Figure 2). Allocation concealment was unclear or at high risk of bias in 20 (77%) studies. Blinding of outcome assessment was also poorly reported with 19 studies showing high or unclear risk of bias for this domain. Domains that performed better were selective reporting with low risk of bias in 21 studies, random sequence generation with low risk of bias in 17 studies and incomplete outcome data showing low risk of bias in 13 studies.

Characteristics of the interventions

Across the interventions assessed in the 26 studies included, 11 were dietary interventions, 8 involved physical activity, and 7 used any combination of diet, physical activity, weight reduction and/or smoking cessation (lifestyle).

Five studies were informed by theory, three used the Trans-Theoretical Model[30,31], one used self-regulation theory[32] and another was informed by contemporary behavioural theory, in particular the self-management approach.[33] Two studies used Motivational Interviewing[34,35], a counselling approach which involves behaviour change strategies.[36]

Only three studies included family members, friends or partners in the intervention to facilitate participant's behaviour change (Supplementary Table S2).[31,37]

Behaviour change techniques

Table 2 outlines the number of behaviour change techniques present in each lifestyle behaviour change intervention. The number of behaviour change techniques used across interventions ranged from 2 to 20.

The top five most frequently observed behaviour change techniques were instruction on how to perform the behaviour (23 interventions, 88%), social support (16, 62%), demonstration of the behaviour (13, 50%), feedback on behaviour (12, 46%), and behavioural practice/rehearsal (12, 46%). Of the 93 possible behaviour change techniques that could have been used, 12 techniques were used in more than 20% of trials, 27 were used at least once and 54 were never used. The mean number of behaviour change techniques was 5, the median was 4 and the range 2-20.

The two studies with the highest number of behaviour change techniques (20 and 18 in each study) were both informed by theory, with a particular focus on self-regulation and self-management.[32,33]

Intervention functions

Table 3 lists the intervention functions present in each study (education, enablement, training, persuasion, modelling, incentivisation, environmental restructuring, coercion and restrictions). The number of functions used across interventions ranged from one to seven.

Education: Education was used most frequently as an intervention function, present in 21 (81%) interventions (Table 3). Examples of educational strategies were: nutritional label reading[38,39], a resistance training booklet for home-based exercise[40], a lecture/workshop about exercise recommendations with demonstrations[30], online education modules on lifestyle modification[41] and a written "six-tip diet" checklist.[42]

Enablement: Eighteen (69%) interventions used enablement. Examples include Motivational Interviewing to improve self-management of diet, lifestyle and physical activity[32,43], supportive telephone calls matching stages of behaviour change[30], self-management techniques to foster self-efficacy[38,39,44] and arranging support from friends and family members and "buddy" visits.[31,33] Four interventions were specifically designed using a self-management approach and assessed self-efficacy as an outcome.[32,33,39,44]

Training: Twelve (46%) interventions included training as an intervention function. Training was used in every intervention targeting physical activity but only used in two dietary interventions and two lifestyle interventions. Examples of training include home-based exercise training, guided exercise training in a gym[40], physical therapy or cardiac rehabilitation facility[45] or hospital[34] and interactive cooking classes.[39]

Persuasion: Four (15%) interventions used persuasion as an intervention function. A dietary intervention aimed to persuade participants about dietary salt intake by displaying test tubes of salt content alongside a range of high-salt food items.[46] In another dietary intervention, positive thinking was applied to participant's goals and dieticians praised progress and focused on positive results.[33] Similarly, a lifestyle intervention used positive reinforcement to increase confidence and celebrate successes related to behaviour change and also discussed lack of exercise, poor dietary habits, risks of not exercising and associated consequences.[31] Only one physical activity intervention used persuasion in designing and displaying printed health messages to promote exercise.[30]

Environmental re-structuring: Four (15%) interventions used environmental restructuring. Two involved placing exercise equipment in the home environment (exercise bicycle, Theraband, weights and Swiss ball)[40,43] and two included adding food products and equipment into the home environment (low sodium/protein meals and water bottles).[33,47]

Modelling: Two (8%) dietary interventions incorporated modelling as an intervention function. Educators used food models and household measuring utensils to model appropriate food portion sizes[46] and food tastings provided an example of low protein meals.[33]

Incentivisation: Two (8%) studies used incentivisation, one in the form of "appreciation gifts" including certificates and mugs[33] and another included "self-rewards" chosen by participants.[32]

Coercion and restrictions: These functions were not used in any of the interventions.

Outcomes

A description of primary outcomes and results reported in studies is included in Table 4. Primary outcomes of studies in this review were diverse and were mainly physiological metrics (for example, eGFR, blood pressure, peak VO2 and sodium or albumin excretion). Only six studies included patient-reported and/or behavioural primary outcomes such as quality of life, fatigue, knowledge, self-efficacy, self-management, exercise and health behaviors.[30,31,44,45,48,49]

Eighteen studies (69%) showed a significant improvement in at least one primary outcome and all of these studies included education, persuasion, modelling and incentivisation as an intervention function (see Supplementary Table S3). A meta-analysis of the data was not possible due to heterogeneity of outcome measures across the included studies. The heterogeneity of outcomes also meant we could not link outcomes with specific behaviour change techniques. Many studies are likely to be underpowered to detect modest effects, and so the absence of a statistically significant effect should not be regarded as evidence of no effect.

DISCUSSION

Behaviour change interventions in trials in patients with CKD mostly focused on diet and physical activity. The primary outcomes of the trials were diverse and most were biochemical outcomes (e.g. eGFR, blood pressure, peak VO2 and sodium or albumin excretion), with few clinical or patient-reported and/or behavioural outcomes such as quality of life, fatigue, knowledge, self-efficacy and self-management.[30,31,38,39,44,45] Only five interventions were underpinned by theory. The most frequently used intervention function was education, followed by enablement and training. Persuasion, environmental restructuring, modelling and incentivisation were used less frequently. Coercion and restrictions (which includes regulation) were not used in any of the studies. The top five most common behaviour change techniques were instruction on how to perform the behaviour, social support, demonstration of the behaviour, feedback on behaviour, and behavioural practice/rehearsal. Identity, scheduled consequences and covert learning were not used in any of the

studies. No association between frequency of functions or behaviour change techniques and the effect of interventions on outcomes could be identified.

The use of multiple behaviour change techniques does not necessarily lead to better outcomes and some evidence suggests that fewer techniques and the right combinations of techniques suited to the context are more effective.[50-52] Education was the most frequent intervention function used across the studies, which may be because it has been consistently shown that patients with CKD lack awareness about lifestyle risk factors and have low health literacy.[10,11,53] Specifically, the behaviour change technique, "instruction on how to perform the behaviour", was the most frequently reported technique, used in all interventions except two. We suggest this is highly applicable because dietary interventions can involve complex dietary restrictions of sodium, protein, potassium and phosphate. Patients have sought practical advice about how to implement these restrictions.[54] However, most educational strategies used a didactic approach, with health professionals verbally conveying information or providing written materials. Patients with CKD prefer multiple problem-solving and collaborative approaches, in partnership with health professionals.[54] Also, written materials for patients with CKD have a reading grade of 9 (age 14-15 years), which is higher than the recommended level (grade 5).[10]

The intervention function "training" was used in every study targeting physical activity but was only used in two dietary interventions. Patients with CKD are overwhelmed by dietary information which can be complex, restrictive, and insensitive to cultural norms.[54] A recent review of educational interventions for CKD patients found that including practical skills and workshops was associated with better outcomes.[55] For example, a low-salt program for Bangladeshi patients with CKD in the United Kingdom included cooking and educational sessions facilitated by Bengali workers in a community kitchen. It targeted both patients and family members who cooked their own low-salt version of Bangladeshi recipes and led to a reduction in salt intake and reduced blood

pressure for participants.[37] Approaches to enabling and training patients for behaviour change incorporating hands-on training may be more effective.

Our findings are similar to recent reviews of behavioural interventions for other conditions (cardiovascular disease, obesity, rheumatoid arthritis, prostate cancer and diabetes), which also found that behavioural interventions are not well-reported, not informed by theory and have diverse outcomes and modes of delivery.[25-27,51,56] The behaviour change techniques associated with goals and planning, feedback and monitoring and social support have also been frequently used in behaviour changes interventions in patients with other chronic conditions. These techniques are proven strategies for behaviour change and in line with evidence-based recommendations for lifestyle modification.[12,13,57]

We identified and described the behaviour change techniques and intervention functions in lifestyle behavioural interventions for patients with CKD with comprehensive evidence-based frameworks. Coding of behaviour change techniques and intervention functions was systematically and independently conducted by three researchers, and risk of bias was assessed. Potential limitations relate to poor reporting. Some interventions may have used behaviour change techniques or intervention functions in their study but did not report them, or details of techniques were unclear. We contacted authors and examined all associated supplementary materials and papers to collect more information.

Lifestyle behaviour change interventions for patients with CKD appear to integrate recommended and proven behaviour change techniques and intervention functions. These techniques such as goals and planning and self-monitoring are important but focus on individual agency rather than external factors. Interventions could be improved by considering the context of behaviour change and the social and physical environment of participants. For example, most of the interventions for physical

activity focused on structured exercise programs and a reliance on equipment (e.g. exercise bikes). Patients with CKD need to be able to integrate physical activity in to their daily lifestyle.[58] However, only one intervention for physical activity gave instructions on how to incorporate physical activity to fit in with daily activities and in environments easily accessible to patients, without the use of equipment.[59] This study reported improvements in cardiopulmonary and functional capacities of overweight patients with CKD.

Optimizing the social environment and arranging support from friends, family and the community may also improve lifestyle behaviour change interventions for patients with CKD. Family support was used rarely in interventions in this review and only included in two studies.[31,37] However, informal caregivers play an important role in the management of CKD and are often required to change their own lifestyle behaviours to support patients with CKD.[60] Characteristics of effective educational interventions for patients with CKD involved the patient's family.[55]

The quality of the design and reporting of lifestyle behaviour change interventions for patients with CKD requires explicit description of behavioural strategies to ensure interventions are generalizable and replicable. There are numerous evidence-based guidelines that recommend the explicit use of behaviour change techniques for addressing lifestyle risk factors in chronic disease prevention and these may be better utilized when designing and reporting interventions for patients with CKD. Recently the National Institute of Health and Care Excellence in the UK published comprehensive guidelines specific to behavioural interventions and lifestyle modification.[12] The World Health Organization's recommendations on behaviour change support this and further reinforce the need to consider the social and environmental determinants of health in changing lifestyle behaviors.[57]

CONCLUSION

Lifestyle interventions in trials conducted in patients with CKD mostly focus on goals and planning, feedback and monitoring and education. However, we suggest that interventions may be improved by using interactive and tailored training, and strategies to help patients incorporate lifestyle modification in their daily activities, and physical and social environments. Explicit application of behaviour change taxonomies may help to increase the effect of lifestyle behaviour change interventions for improved health outcomes in patients with CKD.

Contributors

Research idea and study design: NE, AT, JCC; data acquisition: NE, KM, VS; data analysis/interpretation: NE, AT, JCC, AB, KM, VS; statistical analysis: NE; supervision or mentorship: AT, JCC, AB.

Competing interests

None declared.

Patient consent for publication

Not required.

Data sharing statement

No additional data are available.

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TABLES AND FIGURES

SUPPLEMENTARY MATERIAL

Table 1. Characteristics of included studies

Study	N	CKD Stage	Age (years)	Country	Intervention	Comparator	Primary Outcomes	Study duration (months)
Dietary interventions								
Campbell (2008)	56	CKD4-5	>18	Australia	Individualized nutritional counselling & regular follow up	Usual care	Body composition	3
Clark (2018)	590	CKD3	18-80	Canada	Coaching to increase water intake (drinking containers & water vouchers also provided)	Coaching to maintain usual fluid intake	Change in eGFR	12
De Brito-Ashurst (2013)	56	eGFR <60 mL & BP>130/80 or taking BP medication; Bangladeshi origin	18-74	United Kingdom	Community cooking education sessions facilitated by Bengali workers	Usual care	Reduction in systolic/diastolic BP	6
Dussol (2005)	63	Type I/II diabetic nephropathy, eGFR60-100 mL	40 - 72	France	Low-protein diet with telephone calls every 6 weeks to help change dietary habits	Usual-protein diet	Decline GFR and 24-hour albumin excretion rate	24
MDRD Study (1995)*	840	eGFR 13-55 mL	18-70	United States	Low protein diet with dietician support	Moderate, low & very low protein diets compared	Decline eGFR, dietary satisfaction	45
Mekki (2010)	40	eGFR 60-90mL	47-75	Algeria	Nutritional advice based on Mediterranean diet	Usual care	Dyslipidaemia	3
Meuleman (2016)	138	eGFR≥20 mL	≥18	The Netherlands	Sodium restricted diet with self-management, education, motivational interviewing & self-monitoring	Usual care	Sodium excretion & BP	3
Paes-Barreto (2013)	89	CKD3-5	≥18	Brazil	Intense counselling/education on low protein diet	Standard counselling	Change in protein intake	4
Pisani (2016)	57	CKD3b-5	>18	Italy	Low protein, phosphate & sodium diet, '6-tips diet' checklist	Non-individualized, moderately low protein diet	Protein intake, metabolic parameters and adherence	6

Study	N	CKD Stage	Age (years)	Country	Intervention	Comparator	Primary Outcomes	Study duration (months)
Rosman (1989)	247	CrCl 10-60 ml/min	15-73	The Netherlands	Dietary protein restriction & dietician visits every 3 months	Usual care	Adherence	24
Saran (2017)	58	CKD3-4	>18	United States	Dietary sodium restriction (<2g sodium per day)	Usual diet	Change in hydration status	1
Physical activity interventions								
Aoike (2015)	29	CKD3-4	18-70	Brazil	Home-based moderate-intensity aerobic exercise program	Usual care	Cardiopulmonary/ functional, BP, CrCl, eGFR	3
Barcellos (2018)	150	CKD2-4	>18	Brazil	Aerobic & resistance training	Usual care	Change in eGFR	4
Greenwood (2015)	20	CKD3-4	18-80	United Kingdom	Resistance & aerobic training (3 days per week)	Usual care	Change in eGFR	12
Kao (2012)	94	eGFR≥15 mL	≥39	Taiwan	Group education lecture; individual exercise program Trans-Theoretical Model	Not specified	Exercise behaviour, depression, fatigue	3
Leehey (2016)	32	CKD2-4	49-81	United States	Aerobic & resistance training, home exercise (plus dietary management)	Dietary management	Urine protein to creatinine ratio	12
Rossi (2014)	107	CKD3-4	≥18	United States	Guided exercise twice a week plus usual care	Usual care	Physical function, quality of life	3
Tang (2017)	90	CKD1-3	18-70	China	Individualized exercise program (education & home-based aerobic exercise)	Usual care	Physical function, self-efficacy, anxiety, depression, quality of life	3
Van Craenenbroeck (2015)	40	CKD3-4	≥18	Belgium	Home-based aerobic training program (4 daily cycling sessions, 10 minutes each)	Usual care	Peripheral endothelial function	3
Lifestyle interventions								
Flesher (2011)	40	CKD3-4	18-80	Canada	Individual dietary counselling, group nutrition & cooking classes, exercise program	Usual care	Composite eGFR, TC, urinary sodium, urinary protein & BP	12

Study	N	CKD Stage	Age (years)	Country	Intervention	Comparator	Primary Outcomes	Study duration (months)
Howden (2013)	83	CKD3-4	18-75	Australia	Multi-disciplinary care, lifestyle & aerobic /resistance training	Usual care	Change in CRF	12
Ishani (2016)	601	eGFR <60	>18	United States	Care by a multi-disciplinary team using a telehealth device	Usual care	Composite death, hospitalization, emergency visits & admission to a nursing facility	20
Jiamjariyapon (2017)	442	CKD3-4	18-70	Thailand	Integrated care by multidisciplinary team & community care workers. Group counselling, home visits	Usual care	Change in eGFR	24
Joboshi (2017)	65	Overt proteinuria & clinically diagnosed CKD	38-86	Japan	Self-management program	Standard education	Self-efficacy & self-management behaviour	3
Patil (2013)	76	Diabetic nephropathy	30-70	India	Low-calorie diet, physical activity and behaviour	ACE inhibitor therapy	24-hr urine protein BMI	6
Teng (2013)	160	eGFR≥30 mL/min/1.73 m2	≥ 20	Taiwan	Lifestyle modification program based on Trans-Theoretical Model	Standard education	Health behaviours, knowledge, physical function	12

Abbreviations: eGFR, estimated glomerular filtration rate; BP, blood pressure; MDRD, Modification of Diet in Renal Disease study; CrCl, creatinine clearance; TC, total cholesterol; CRF, cardiorespiratory fitness.

*MDRD study described in two main articles: Gillis et al (1995) and Coyne et al (1995)

Table 2. Cross matrix of behaviour change techniques and lifestyle behaviour change trials

	Meuleman (2016)	MDRD Study (1995)	De Brito-Ashurst (2013)	Paes-Barreto (2013)	Campbell (2008)	Rosman (1989)	Dussol (2005)	Pisani (2016)	Saran (2017)	Clark (2018)	Mekki (2010)	Tang (2017)	Kao (2012)	Greenwood (2015)	Rossi (2014)	Aoike (2015)	Barcellos (2018)	Van Craenenbroeck (2015)	Leehey (2016)	Howden (2013)	Ishani (2016)	Joboshi (2017)	Teng (2013)	Flesher (2011)	Jiamjariyapon (2017)	Patil (2013)
1. Goals and planning	**Diet**											**Physical Activity**								**Lifestyle**						
1.1. Goal setting (behaviour)	■	■	■		■							■	■		■					■						
1.2. Problem solving	■	■			■							■								■		■	■			
1.3. Goal setting (outcome)	■																				■	■	■	■		
1.4. Action planning	■											■	■		■											
1.5. Review behaviour goal(s)	■				■							■											■			
1.7. Review outcome goal(s)	■	■	■			■								■		■					■	■				
1.8. Behavioural contract	■	■										■	■													
1.9. Commitment		■																								
2. Feedback and monitoring																										
2.1. Monitoring of behaviour by others without feedback							■	■			■										■					■
2.2. Feedback on behaviour		■	■	■	■	■			■			■	■			■					■	■			■	
2.3. Self-monitoring of behaviour	■	■										■	■	■						■	■	■				
2.4. Self-monitoring of outcome(s) of behaviour	■	■																						■		
2.6. Biofeedback	■	■																								
2.7. Feedback on outcome(s) of behaviour	■																									
3. Social support																										
3.1. Social support (unspecified)	■		■	■	■		■					■	■			■	■	■	■		■	■	■	■	■	
3.2. Social support (practical)						■														■						
3.3. Social support (emotional)	■	■							■					■												
4. Shaping knowledge																										
4.1. Instruction on how to perform the behaviour	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■			■	■	■

4.4. Behavioural experiments			■																							
5. Natural consequences																										
5.1. Information about health consequences	■		■		■				■			■	■										■			
5.2. Salience of consequences				■																						
5.4. Monitoring of emotional consequences												■														
6. Comparison of behaviour																										
6.1. Demonstration of the behaviour		■	■	■								■	■	■	■	■	■	■		■				■	■	
6.2. Social comparison	■																									
7. Associations																										
7.1. Prompts/cues	■																									
8. Repetition and substitution																										
8.1. Behavioural practice/rehearsal		■	■	■								■	■	■	■	■	■	■		■				■		
8.2. Behaviour substitution			■	■		■	■	■																	■	
8.4. Habit reversal			■	■		■		■																	■	
8.6. Generalisation of target behaviour														■	■					■						
8.7. Graded tasks	■		■							■		■		■	■		■					■				
9. Comparison of outcomes																										
9.2. Pros and cons				■									■										■			
10. Reward and threat																										
10.3. Non-specific reward	■																									
10.4. Social reward		■																								
10.10. Reward (outcome)		■																								
11. Regulation																										
11.2. Reduce negative emotions		■																								
11.3. Conserving mental resources		■																								
12. Antecedents																										
12.5. Adding objects to the environment		■								■				■			■			■						
15. Self-belief																										
15.1. Verbal persuasion about capability																							■			
15.3. Focus on past success	■																									
Number of BCTs	**20**	**18**	**12**	**9**	**7**	**6**	**4**	**4**	**4**	**2**	**2**	**14**	**11**	**9**	**7**	**6**	**6**	**4**	**2**	**9**	**7**	**7**	**7**	**6**	**4**	**4**

Table 3. Cross matrix of intervention functions and lifestyle behaviour change trials

		Intervention functions						
Studies	**Type of intervention**	**Education**	**Enablement**	**Training**	**Persuasion**	**Environmental restructuring**	**Modelling**	**Incentivisation**
Campbell (2008)	**Diet**	■	■					
Clark (2018)			■			■		
De Brito-Ashurst (2013)		■		■				
Dussol (2005)		■	■					
MDRD Study (1995)		■	■	■	■	■	■	■
Mekki (2010)		■						
Meuleman (2016)		■	■					■
Paes-Barreto (2013)		■			■		■	
Pisani et al (2016)		■						
Rosman (1989)		■	■					
Saran (2017)		■	■					
Aoike et al (2015)	**Physical Activity**	■	■	■				
Barcellos (2018)			■	■				
Greenwood (2015)			■	■		■		
Kao et al (2012)		■	■	■	■			
Leehey (2016)				■				
Rossi et al (2014)		■		■				
Tang (2017)		■	■	■				
Van Craenenbroeck (2015)				■				
Flesher et al (2011)	**Lifestyle**	■	■	■				
Howden et al (2013)		■	■	■		■		
Ishani (2016)		■	■					
Jiamjariyapon (2017)		■	■					
Joboshi (2017)		■	■					
Patil (2013)		■						
Teng et al (2013)		■	■		■			
Total		**21**	**18**	**12**	**4**	**4**	**2**	**2**

Table 4. Effects of the behaviour change interventions on the primary outcome(s)

Study	Primary outcome/s	Measures	Intervention (n)	Control (n)	Intervention[a]	Control[a]	Mean difference (95% CI)	*p*
Dietary interventions								
Campbell (2008)	Body composition	Body cell mass, %	29	27	2.0 (1.9 to 5.9)[b]	1.5 (5.5 to 2.5)[b]	3.5 (2.1 to 9.1)	0.2
		Body cell mass, kg			0.5 (1.8 to 0.8)[b]	0.5 (0.7 to 1.8)[b]	1.1 (0.7 to 2.9)	0.2
Clark (2018)	Change in eGFR	Change eGFR, mL/min/1.73m^2	311	308	−2.2 (−3.3 to −1.1)[b]	−1.9 (−2.9 to −0.9)[b]	−0.3 (−1.8 to 1.2)	0.74
De Brito-Ashurst (2013)	Change in BP	Reduction systolic/diastolic BP	25	23	-	-	-8mmHg (-11 to -5) / 2(-4 to-2)	<0.001
Dussol (2005)	Decrease in eGFR	Decrease eGFR, mL/min/1.73m^2	25	22	-7±11	-5±15	-	-
	24-hour albumin excretion rate	Microalbuminuria, mg/d			+114±364	+156±486	-	-
MDRD[c] Study 1 (1995)	Dietary satisfaction (Study A: GFR 25-55ml/min. 1.73m2)	Dietary satisfaction score	220	221	3.6 ±1.0	3.8 ±1.0	-	<0.05
	Dietary satisfaction (Study B: GFR 13-24ml/min. 1.73m2	Dietary satisfaction score	65	59	3.1 ±0.9	3.6 ±0.9	-	<0.01
MDRD[c] Study 2 (1996)	Decline eGFR (Study A: GFR 25-55ml/min. 1.73m2)	Decline eGFR, baseline to 3 years	291	394	-	-	3.8 (4.2)[d]	-
	Decline eGFR (Study B: GFR 13-24ml/min. 1.73m2)	Decline eGFR, baseline to 3 years	126	129	-	-	4.0 (3.1)[d]	-
Mekki (2010)	Total cholesterol (TC)	TC/mmol L-1	20	20	4.1±0.5	5.4±0.4	-	<0.05
	Triacylglycerols (TG)	TG/mmol L-1			2.9±0.1	3.9 ±0.1	-	<0.05
Meuleman (2016)	Blood pressure	Office systolic BP, mmHg	67	71	-	-	-7.3 (-12.7 to -1.9)[e]	<0.01
		Office diastolic BP, mmHg			-	-	-3.8 (-6.9 to -0.6)[l]	<0.05
	Sodium excretion	Sodium excretion rate, mmol/24h			-	-	2.9 (-21.6 to 27.3)[l]	
Paes-Barreto (2013)	Change in protein intake	Change protein intake, g/day	43	46	-20.7 (-30.9%)[f]	-10.5 (-15.1%)[e]	-	0.04
Pisani (2016)	Protein intake	Change protein intake, g/kg/day	27	27	-0.1 (-0.17 to -0.03)[b]	-0.2 (-0.28 to -0.13)[b]	-	0.04
	UUN excretion	Change UUN, g/day			-1.3 (-2.1 to -0.5)[b]	-2.8 (-3.6 to -2)[b]	-	0.008
	SUN	Change SUN, mg/dL			2.96 (-7.71 to13.64)[b]	-16.63 (-27.3 to -5.96)[b]	-	0.012
	Urinary phosphate excretion	Change phosphate excretion, mg/day			-27.6 (-93.7 to 38.4)[b]	-165.3 (-231.3 to -99.2)[b]	-	0.005
	Serum phosphate concentration	Change serum phosphate, mg/dL			0.2 (0 to 0.4)[b]	-0.1 (-0.3 to 0.2)[b]	-	0.093
	Adherence	Met criteria, n, %			19 (70%)[g]	11 (44%)[f]	-	-
Rosman (1989)	Adherence (Group A1 & B: CrCl >30)	Median 24 hr urea excretion mmol/24 hr	45	47	-	-	-	<0.01
	Adherence (Group A2 & C: CrCl≤30)	Median 24 hr urea excretion mmol/24 hr	23	17	-	-	-	<0.01
Saran (2017)	Change hydration status	Extracellular Volume, L	29	29	-	-	-1.02 (-1.48 to 0.56)[h]	<0.001
		Intracellular Volume, L			-	-	-0.06 (-0.12 to 0.01)[g]	0.02
Physical activity interventions								
Aoike (2015)	Cardiopulmonary parameters	Maximal ventilation, L/min	14	15	90.7 ± 28.1	76.6 ± 23.3	-	0.003
		Ventilatory threshold,			26.1 ± 7.0	24.2 ± 7.1	-	0.302

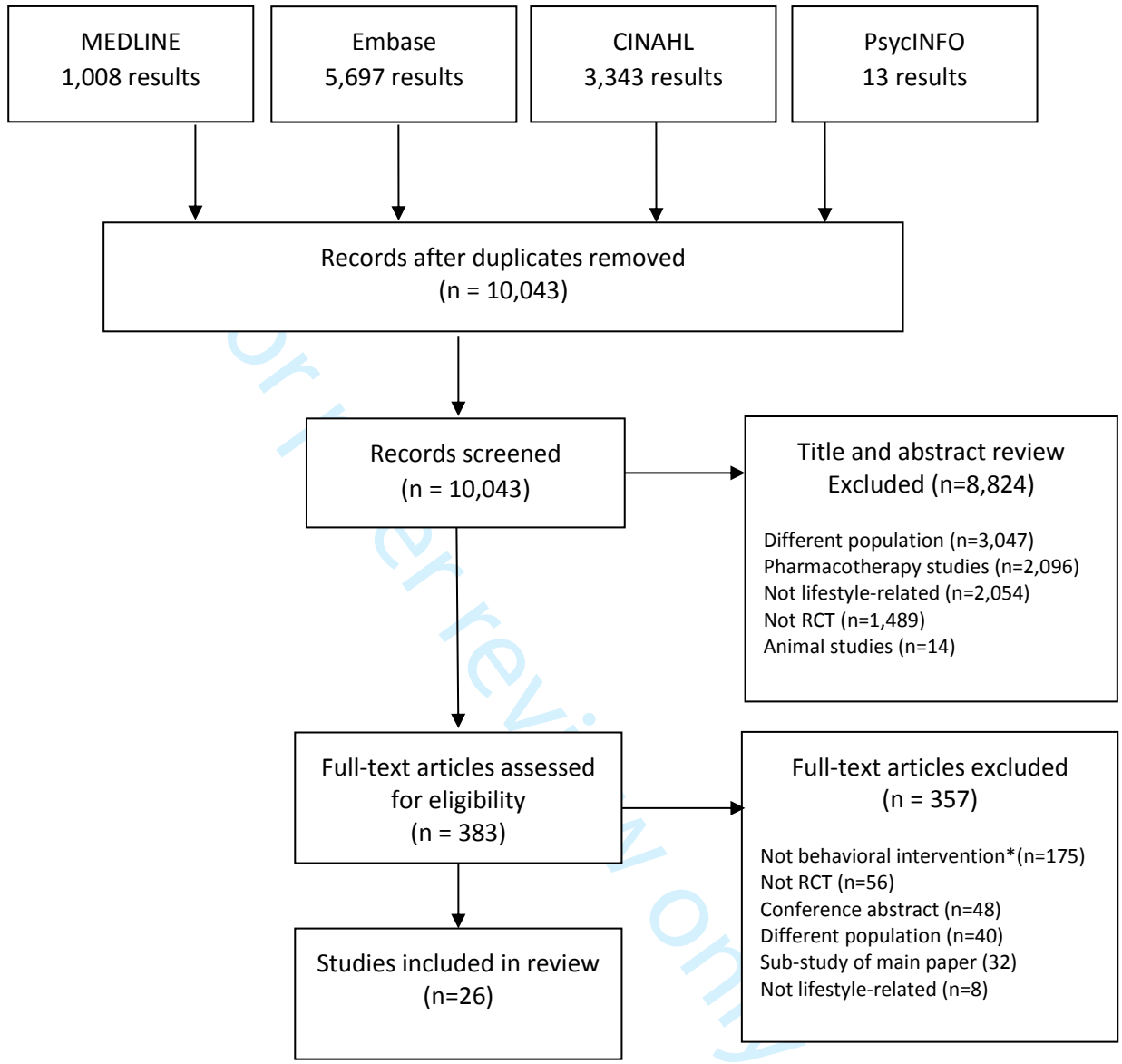
Study	Primary outcome/s	Measures	Intervention (n)	Control (n)	Intervention[a]	Control[a]	Mean difference (95% CI)	*p*
		VO_2peak, Ml/kg/min						
		VO_2 in respiratory compensation point, Ml/kg/min			21.7 ± 5.5	19.0 ± 5.6	-	0.073
		Speed in respiratory compensation point, Km/h			6.8 ± 1.1	5.8 ± 1.0	-	<0.001
	Functional capacity	6MWT, minutes			583.1 ± 85.2	561.2 ± 91.2	-	0.028
		Time up /go test, seconds			5.82 ± 1.39	6.42 ± 1.11	-	0.001
		Arm curl test, repetitions			22.8 ± 4.8	18.1 ± 3.1	-	<0.001
		STST, repetitions			24.0 ± 7.1	18.3 ± 4.8	-	<0.001
		2-min step test, steps			219.3 ± 36.7	179.9 ± 36.3	-	<0.001
		Back scratch test, cm			6.4 ± 6.6	12.6 ± 9.9	-	0.05
	Systolic & diastolic BP	Systolic BP, mmHg			118.7 ± 7.3	126.8 ± 6.7	-	0.012
		Diastolic BP, mmHgP			76.1 ± 4.4	81.0 ± 3.7	-	0.038
	Renal function	Serum creatinine, mg/dL			2.6 ± 1.1	3.2 ± 1.4	-	0.215
		eGFR, mL/min/1.73m^2			31.9 ± 13.7	23.9 ± 12.2	-	0.046
Barcellos (2018)	Mean change in eGFR	Change eGFR, mL/min/1.73m^2	76	74	61.5 (57.0 to 66.1)[b]	59.0 (54.2 to 63.8)[b]	0.7 (-4.0 to 5.4)	-
Greenwood (2015)	Mean change in eGFR	Change eGFR, mL/min/1.73m^2	8	10	-3.8±2.8	-8.5±6.4	7.8±3.0 (1.1 to 13.5)	0.02
Kao (2012)	Depression	Change depression (Beck Depression Inventory-II scale)	45	49	-3.71[i]	1.33[h]	-	<0.01
	Fatigue	Change fatigue			-4.74[h]	1.91[h]	-	<0.001
	Exercise behaviour	Change weekly exercise			4.28[h]	-1.24[h]	-	<0.001
Leehey (2016)	UPCR ratio	UPCR (mg/g) at 52 wks	14	18	405 (225 to 1038)[j]	618 (323 to 1155)[i]	-	0.39
Rossi (2014)	Physical function	6MWT, minutes	59	48	210.4±266	-10±219.9	-	<0.001
		STST, seconds			26.9±27% age prediction[k]	0.7±12.1% age prediction[j]	-	<0.001
		Gait speed, cm			9.5 (-36.4 to 34)[i]	0 (-9 to 13)[i]	-	0.76
	QoL (RAND SF-36),	Role functioning/physical			19.0 ±31.7	-8.9 ±38.4	-	<0.001
	mean change from	Physical functioning			11.1±19.3	-0.7 ±18.7	-	0.004
	baseline	Energy/fatigue			9.8 ±17.6	0.5 ±18.0	-	0.01
		General health			4.9 ±15.3	-1.2 ±11.5	-	0.03
		Pain			5.7 ±20.0	-3.8 ±24.4	-	0.04
		Emotional wellbeing			4.2 ±16.9	-0.4 ±17.1	-	0.2
		Social functioning			4.2 ±20.8	1.6 ±22.6	-	0.57
		Role functioning/emotional			6.9 ±24.5	1.9 ±29.2	-	0.38
Tang (2017)	Physical function	Change 6MWT, minutes	42	42	41.93 ±14.57	-5.05 ±14.81	-	<0.001
		Change STST, seconds			-2.68 ±1.95	0.49 ±2.07	-	<0.001
	Self-efficacy	Change self-efficacy score			6.64 ±6.92	-3.72 ±6.80	-	<0.001
	Anxiety	Change HAD-A score			-1.02±1.47	0.21 ±2.17	-	0.003
	Depression	Change HAD-D score			-0.76 ±1.32	0.31±1.84	-	0.003
	QoL (KDQOL-SF),	Symptom/problem list			2.49 ±4.81	0.38 ±6.97	-	0.007
	mean change from	Effects of kidney disease			1.90 ±5.22	−1.56 ±9.64	-	0.005
	baseline	Burden of kidney disease			−0.45 ±15.27	−15.3 ±18.11	-	<0.001
		SF-12 PCS			1.08 ±3.60	−0.74 ±4.55	-	0.045
		SF-12 MCS			1.87 ±5.69	−0.73 ±4.53	-	0.002

Study	Primary outcome/s	Measures	Intervention (n)	Control (n)	Intervention[a]	Control[a]	Mean difference (95% CI)	*p*
Van Craenenbroeck (2015)	Peripheral endothelial function	Flow mediated dilation of brachial artery	19	21	4.6 ±3.0	5.3 ± 3.1	0.32 (-1.88 to 2.53)	0.9
Lifestyle interventions								
Flesher (2011)	Composite of eGFR, TC, US, UP, BP	Number of improved endpoints	23	17	83	30		0.028
Howden (2013)	Change in CRF	VO_2, ml/kg per minute	36	36	2.8±0.7	0.3±0.9	-	0.004
Ishani (2016)	Composite death, hospitalization, emergency visits, admission nursing facility	Occurrence of primary outcome/hazard ratio	451	150	208 (46.2%)	70 (46.7%)	-	0.9
Jiamjariyapon (2017)	Mean change in eGFR	Change eGFR, mL/min/1.73m^2	234	208	42.4 ±1.5	39.9 ±2.8	2.74 (0.60-4.50)	0.009
Joboshi (2017)	Perceived behaviour	Self-efficacy	32	29	r=0.27, U=318.5[l]	-	-	0.035
		Self-management			r=0.27, U=310.0[k]	-	-	0.026
Patil (2013)	24-hr urine protein	24-hr urine protein, g/d	23 (B)	22 (A),31 (C)	1284.74 ± 1079.94	A: 1079.27 ±1269.20; C: 1187.61±756.92	-	-
	BMI	Change in BMI (paired t-test)			-1.95 ±1.10	A: -0.15 ±0.38 (p=0.069); C: -2.56 ±0.68 (p=0.000)	-	0.000
Teng (2013)	Health-promotion lifestyle behaviours (HPLP-IIC)	Stress management	45	45	-	-	2.76	0.10
		Interpersonal relations			-	-	3.88	0.05
		Health responsibility			-	-	13.63	0.001
		Physical activity			-	-	7.50	0.01
		Spiritual growth			-	-	2.79	0.10
		Nutrition			-	-	2.62	0.11
	Renal function protection knowledge	Knowledge renal function, Chinese herbs & CKD diet			-	-	No data	0.001
	Physical function	6MWT, minutes	45	45	420.4 ±81.2	368.5 ±99.7	-	0.04

Abbreviations: CI, Confidence interval; eGFR, estimated glomerular filtration rate; BP, blood pressure; UUN, urinary urea nitrogen; SUN, Serum urea nitrogen; 6MWT, 6 Minute Walk Test; STST, Sit to Stand Test; UPCR, Urine protein to creatinine ratio; QoL, Quality of life; RAND SF-36, 36-Item Short Form Survey; HAD-A/HAD-D, Hospital Anxiety & Depression Scale; KDQOL-SF, Kidney Disease & Quality of Life Short Form; SF-12 PCS/MCS, Physical and Mental Health Composite Scores; TC, Total cholesterol; US, Urinary sodium; UP, Urinary protein; CRF, Cardiorespiratory fitness; BMI, Body Mass Index; HPLP-IIC, Health Promoting Lifestyle Profile-II Chinese version (questionnaire)

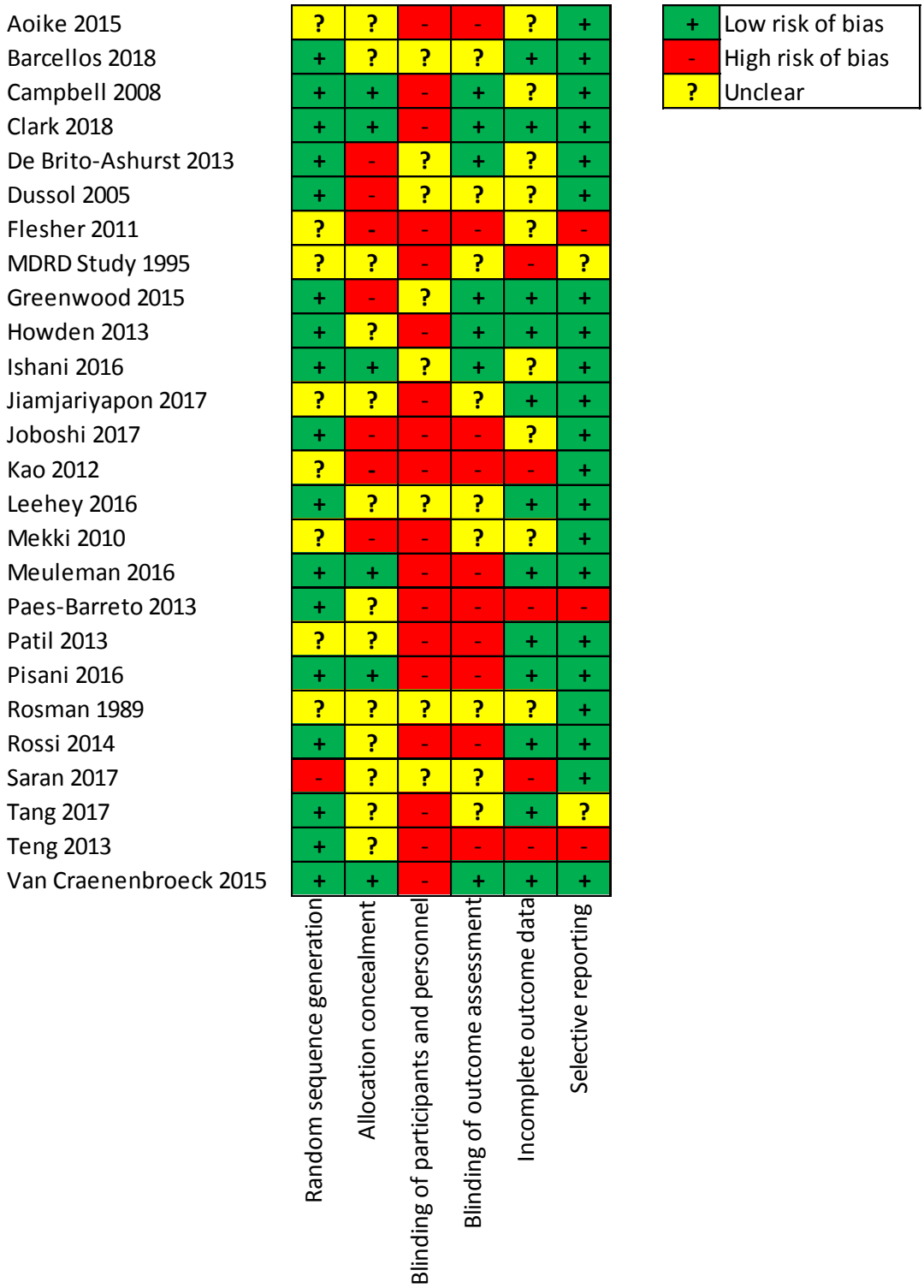
[a] Unless otherwise indicated, values are shown as mean+/-SD
[b] Mean change (95% confidence interval)
[c] Modification of Diet in Renal Disease (MDRD) study (Gillis et al (1995), Coyne et al (1995))
[d] Mean decline +/- SD
[e] Mean change from baseline after 6 months
[f] Mean change and % reduction from baseline values
[g] Number of participants who met adherence criteria (n,%)
[h] p-value calculated as p<0.05 x group interaction (Aoike 2015)
[i] Paired T test
[j] Median (IQR)
[k] STST results standardized as a percentage of age-predicted value using prediction formulas (Rossi 2014)
[l] Effect size (r) Median, Mann-Whitney's U Test

Figure 1. PRISMA flowchart of included/excluded studies



*A behavioral intervention explicitly describes a behavior change technique which can be coded using the Behavior Change Technique Taxonomy version 1

Figure 2. Risk of bias for individual studies (n=26)



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2, 3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3, 6
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6, 7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	7, FileS2
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6, 7, 34
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7, 9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	12
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	12, 13

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	n/a
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	n/a
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	9
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	9, 25-27
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	9
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	12, 13, 30-32
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	n/a
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	9, 34
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	n/a
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13-15
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	16
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	18

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

File S2. Search strategies

Search results: MEDLINE via OvidSP (1946 to 20 September 2018)

#	Search terms	Results
1	exp Renal Insufficiency/	152,141
2	exp Renal Insufficiency, Chronic/	101,640
3	Kidney diseases/	79,478
4	(chronic kidney or chronic renal).tw.	59,047
5	(CKD or CRD).tw.	19,371
6	(predialysis or pre-dialysis).tw.	4,177
7	1 or 2 or 3 or 4 or 5 or 6	243,965
8	exp health behaviour/	163,935
9	exp habits/	34,134
10	lifestyle$.tw.	66,158
11	exp Health promotion/	67,019
12	exp Health education/	155,589
13	exp Diet/	240,468
14	exp Diet Therapy/	48,800
15	exp Food Habits/	33,822
16	Fruit/ and Vegetables/	9,462
17	((diet or diets or dietary) adj5 (Mediterranean or vegetarian or plant-based or American Heart Association* or DASH or western or seafood)).tw.	9,130
18	((diet or dietary or nutrition*) adj (survey* or record or records or score)).tw.	6,572
19	exp Exercise/	160,256
20	exp Exercise therapy/	42,215
21	exp Exercise movement techniques/	6,911
22	aerobic exercise/	90,067
23	exp Smoking/	140,996
24	exp Smoking cessation/	25,651
25	exp Drinking behaviour/	68,788
26	exp Alcoholism/	72,211
27	exp Alcoholic intoxication/	12,043
28	exp Binge drinking/	1,195
29	8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28	1,027,712
30	randomized controlled trial.pt.	466,609
31	pragmatic clinical trial.pt.	761
32	controlled clinical trial.pt.	92,933
33	randomized.ab.	354,404
34	placebo.ab.	174,060
35	clinical trials as topic.sh.	180,151
36	randomly.ab.	243,654
37	trial.ti.	160,708
38	30 or 31 or 32 or 33 or 34 or 35 or 36 or 37	1,034,856
39	7 and 29 and 38	1,008

Search results: Embase via OvidSP (1996 to 20 September 2018)

#	Search terms	Results
1	exp chronic kidney disease/	62,294
2	exp kidney disease/	849,346
3	(chronic kidney or chronic renal).tw.	92,692
4	(CKD or CRD).tw.	37,030
5	(predialysis or pre-dialysis).tw.	6,221
6	1 or 2 or 3 or 4 or 5	863,647
7	exp health behaviour/	349,149
8	exp habit	28,571
9	exp lifestyle	113,466
10	exp lifestyle modification	30,765
11	exp sedentary lifestyle	9,819
12	lifestyle$.tw.	100,473
13	exp health promotion/	85,281
14	exp health education/	285,678
15	exp diet	324,233
16	exp diet therapy	333,497
17	exp feeding behaviour	160,127
18	exp renal diet	92
19	Fruit/ and Vegetables/	20,205
20	((diet or diets or dietary) adj5 (Mediterranean or vegetarian or plant-based or American Heart Association* or DASH or western or seafood)).tw.	14,599
21	((diet or dietary or nutrition*) adj (survey* or record or records or score)).tw.	8,893
22	exp exercise	312,543
23	exp physical activity	370,197
24	exp smoking	312,045
25	exp smoking cessation	50,560
26	exp smoking habit	22,226
27	exp smoking cessation program	3,316
28	exp drinking behaviour	45,218
29	exp drinking pattern	45,218
30	exp binge drinking	3,432
31	exp alcohol consumption	113,850
32	exp alcohol abuse	37,477
33	exp alcohol abstinence	5,831
34	exp alcohol intoxication	12,743
35	exp alcoholism	119,763
36	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35	2,186,119
37	randomized.ab.	540,955
38	placebo.ab.	249,626
39	randomly.ab.	354,161
40	trial.ti.	236,549
41	37 or 38 or 39 or 40	1,068,038
44	6 and 36 and 41	5,679

Search results: CINAHL via EBSCO (1982 to 20 September 2018)

#	Search terms	Results
S21	S3 AND S20	3,343
S20	S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19	440,706
S19	(MH "Alcohol Drinking+")	14,329
S18	(MH "Alcoholic Intoxication+")	1,759
S17	(MH "Alcoholism") OR (MH "Alcoholic Intoxication+")	10,496
S16	(MH "Drinking Behaviour+")	16,090
S15	(MH "Smoking+")	39,165
S14	(MH "Aerobic Exercises+")	24,457
S13	(MH "Therapeutic Exercise+")	32,306
S12	(MH "Exercise+")	62,514
S11	"fruit and vegetables"	736
S10	(MH "Diet Therapy+")	15,217
S9	(MH "Diet+")	58,812
S8	(MH "Health Education+")	83,615
S7	(MH "Health Promotion+")	37,813
S6	(MH "Life Style+")	124,973
S5	(MH "Habits+")	45,961
S4	(MH "Health Behaviour+")	57,214
S3	S1 OR S2	33,991
S2	MH "kidney diseases+"	33,991
S1	(MH "Renal Insufficiency+") OR (MH "Renal Insufficiency, Chronic+")	17,914

PsycINFO via OvidSP (1806 to 20 September 2018)

#	Search terms	Results
1	exp Kidney Diseases/	1,983
2	(chronic kidney or chronic renal).tw.	1,148
3	(predialysis or pre-dialysis).tw.	70
4	(CKD or CRD).tw.	476
5	1 or 2 or 3 or 4	2,613
6	exp Health Behaviour/	26,049
7	exp HABITS/	33,531
8	exp Eating Behaviour/	18,434
9	exp LIFESTYLE/	10,664
10	exp Lifestyle Changes/	1,163
11	exp Health Promotion/	22,016
12	exp Health Education/	17,199
13	exp Behaviour Change/	11,102
14	exp DIETS/	11,487
15	exp Food Preferences/	4,394
16	"fruit and vegetable*".tw.	2,354
17	((diet or diets or dietary) adj5 (Mediterranean or vegetarian or plant-based or American Heart Association* or DASH or western or seafood)).tw.	706
18	((diet or dietary or nutrition*) adj (survey* or record or records or score)).tw.	582
19	exp Physical Activity/	35,706
20	exp Exercise/	23,406
21	aerobic exercise/	1,557
22	exp SMOKING CESSATION/	12,102
23	exp TOBACCO SMOKING/	29,024
24	exp Drinking behaviour/	68,488
25	exp Alcohol Drinking Patterns/	63,023
26	exp ALCOHOLISM/	29,297
27	exp Binge Drinking/	2,069
28	exp Alcohol Abuse/	45,860
29	exp Alcohol Intoxication/	3,046
30	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29	228,162
31	randomized.ab.	57,824
32	placebo.ab.	36,556
33	randomly.ab.	65,494
34	trial.ti.	26,290
35	31 or 32 or 33 or 34	149,264
36	5 and 30 and 35	13

Table S1. Behaviour Change Technique Taxonomy version 1 (Available as a public resource from Behaviour Change Technique Taxonomy Online Training website: http://www.bct-taxonomy.com/)

Page	Grouping and BCTs
1	**1. Goals and planning**
	1.1. Goal setting (behavior) 1.2. Problem solving 1.3. Goal setting (outcome) 1.4. Action planning 1.5. Review behavior goal(s) 1.6. Discrepancy between current behavior and goal 1.7. Review outcome goal(s) 1.8. Behavioral contract 1.9. Commitment
3	**2. Feedback and monitoring**
	2.1. Monitoring of behavior by others without feedback 2.2. Feedback on behaviour 2.3. Self-monitoring of behaviour 2.4. Self-monitoring of outcome(s) of behaviour 2.5. Monitoring of outcome(s) of behavior without feedback 2.6. Biofeedback 2.7. Feedback on outcome(s) of behavior
5	**3. Social support**
	3.1. Social support (unspecified) 3.2. Social support (practical) 3.3. Social support (emotional)
6	**4. Shaping knowledge**
	4.1. Instruction on how to perform the behavior 4.2. Information about Antecedents 4.3. Re-attribution 4.4. Behavioral experiments
7	**5. Natural consequences**
	5.1. Information about health consequences 5.2. Salience of consequences 5.3. Information about social and environmental consequences 5.4. Monitoring of emotional consequences 5.5. Anticipated regret 5.6. Information about emotional consequences
8	**6. Comparison of behaviour**
	6.1. Demonstration of the behavior 6.2. Social comparison 6.3. Information about others' approval
9	**7. Associations**
	7.1. Prompts/cues 7.2. Cue signalling reward 7.3. Reduce prompts/cues 7.4. Remove access to the reward 7.5. Remove aversive stimulus 7.6. Satiation 7.7. Exposure 7.8. Associative learning
10	**8. Repetition and substitution**
	8.1. Behavioral practice/rehearsal 8.2. Behavior substitution 8.3. Habit formation 8.4. Habit reversal 8.5. Overcorrection 8.6. Generalisation of target behavior 8.7. Graded tasks
11	**9. Comparison of outcomes**
	9.1. Credible source 9.2. Pros and cons 9.3. Comparative imagining of future outcomes
12	**10. Reward and threat**
	10.1. Material incentive (behavior) 10.2. Material reward (behavior) 10.3. Non-specific reward 10.4. Social reward 10.5. Social incentive 10.6. Non-specific incentive 10.7. Self-incentive 10.8. Incentive (outcome) 10.9. Self-reward 10.10. Reward (outcome) 10.11. Future punishment
15	**11. Regulation**
	11.1. Pharmacological support 11.2. Reduce negative emotions 11.3. Conserving mental resources 11.4. Paradoxical instructions
16	**12. Antecedents**
	12.1. Restructuring the physical environment 12.2. Restructuring the social environment 12.3. Avoidance/reducing exposure to cues for the behavior 12.4. Distraction 12.5. Adding objects to the environment 12.6. Body changes
17	**13. Identity**
	13.1. Identification of self as role model 13.2. Framing/reframing 13.3. Incompatible beliefs 13.4. Valued self-identify 13.5. Identity associated with changed behavior
18	**14. Scheduled consequences**
	14.1. Behavior cost 14.2. Punishment 14.3. Remove reward 14.4. Reward approximation 14.5. Rewarding completion 14.6. Situation-specific reward 14.7. Reward incompatible behavior 14.8. Reward alternative behavior 14.9. Reduce reward frequency 14.10. Remove punishment
19	**15. Self-belief**
	15.1. Verbal persuasion about capability 15.2. Mental rehearsal of successful performance 15.3. Focus on past success 15.4. Self-talk
19	**16. Covert learning**
	16.1. Imaginary punishment 16.2. Imaginary reward 16.3. Vicarious consequences

BCT Taxonomy (v1): 93 hierarchically-clustered techniques

Note for Users

The definitions of Behavior Change Techniques (BCTs):

i) contain verbs (e.g., provide, advise, arrange, prompt) that refer to the action(s) taken by the person/s delivering the technique. BCTs can be delivered by an 'interventionist' or self-delivered

ii) contain the term **"behavior"** referring to a single action or sequence of actions that includes the performance of **wanted** behavior(s) and/or **inhibition** (non-performance) of **unwanted** behavior(s)

iii) note alternative or additional coding where relevant

iv) note the technical terms associated with particular theoretical frameworks where relevant (e.g. 'including implementation intentions)

No.	Label	Definition	Examples
1. Goals and planning			
1.1	***Goal setting (behavior)***	Set or agree on a goal defined in terms of the behavior to be achieved *Note: only code goal-setting if there is sufficient evidence that goal set as part of intervention; if goal unspecified or a behavioral outcome, code **1.3, Goal setting (outcome)**; if the goal defines a specific context, frequency, duration or intensity for the behavior, also code **1.4, Action planning***	Agree on a daily walking goal (e.g. 3 miles) with the person and reach agreement about the goal Set the goal of eating 5 pieces of fruit per day as specified in public health guidelines
1.2	***Problem solving***	Analyse , or prompt the person to analyse, factors influencing the behavior and generate or select strategies that include overcoming barriers and/or increasing facilitators (includes '**Relapse Prevention**' *and '***Coping Planning***'*) *Note: barrier identification without solutions is not sufficient. If the BCT does not include analysing the behavioral problem, consider **12.3, Avoidance/changing exposure to cues for the behavior, 12.1, Restructuring the physical environment, 12.2, Restructuring the social environment,** or **11.2, Reduce negative emotions***	Identify specific triggers (e.g. being in a pub, feeling anxious) that generate the urge/want/need to drink and develop strategies for avoiding environmental triggers or for managing negative emotions, such as anxiety, that motivate drinking Prompt the patient to identify barriers preventing them from starting a new exercise regime e.g., lack of motivation, and discuss ways in which they could help overcome them e.g., going to the gym with a buddy

1.3	***Goal setting (outcome)***	Set or agree on a goal defined in terms of a positive **outcome** of wanted behavior *Note: only code guidelines if set as a goal in an intervention context; if goal is a behavior, code **1.1, Goal setting (behavior)**; if goal unspecified code **1.3, Goal setting (outcome)***	Set a weight loss goal (e.g. 0.5 kilogram over one week) as an outcome of changed eating patterns
1.4	***Action planning***	Prompt detailed planning of performance of the behavior (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive) (includes '**Implementation Intentions**') *Note: evidence of action planning does not necessarily imply goal setting, only code latter if sufficient evidence*	Encourage a plan to carry condoms when going out socially at weekends Prompt planning the performance of a particular physical activity (e.g. running) at a particular time (e.g. before work) on certain days of the week
1.5	***Review behavior goal(s)***	Review behavior goal(s) jointly with the person and consider modifying goal(s) or behavior change strategy in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of (or in addition to) the first, or no change *Note: if goal specified in terms of behavior, code **1.5, Review behavior goal(s)**, if goal unspecified, code **1.7, Review outcome goal(s);** if discrepancy created consider also **1.6, Discrepancy between current behavior and goal***	Examine how well a person's performance corresponds to agreed goals e.g. whether they consumed less than one unit of alcohol per day, and consider modifying future behavioral goals accordingly e.g. by increasing or decreasing alcohol target or changing type of alcohol consumed
1.6	***Discrepancy between current behavior and goal***	Draw attention to discrepancies between a person's current behavior (in terms of the *form, frequency, duration, or intensity* of that behavior) and the person's previously set outcome goals, behavioral goals or action plans (goes beyond self-monitoring of behavior) *Note: if discomfort is created only code **13.3, Incompatible beliefs** and not **1.6, Discrepancy between current behavior and goal**; if goals are modified, also code **1.5, Review behavior goal(s)** and/or **1.7, Review outcome goal(s)**; if feedback is provided, also code **2.2, Feedback on behaviour***	Point out that the recorded exercise fell short of the goal set

1.7	***Review outcome goal(s)***	Review outcome goal(s) jointly with the person and consider modifying goal(s) in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of, or in addition to the first *Note: if goal specified in terms of behavior, code **1.5, Review behavior goal(s)**, if goal unspecified, code **1.7, Review outcome goal(s);** if discrepancy created consider also **1.6, Discrepancy between current behavior and goal***	Examine how much weight has been lost and consider modifying outcome goal(s) accordingly e.g., by increasing or decreasing subsequent weight loss targets
1.8	***Behavioral contract***	Create a written specification of the behavior to be performed, agreed on by the person, and witnessed by another *Note: also code **1.1, Goal setting (behavior)***	Sign a contract with the person e.g. specifying that they will not drink alcohol for one week
1.9	***Commitment***	Ask the person to affirm or reaffirm statements indicating commitment to change the behavior *Note: if defined in terms of the behavior to be achieved also code **1.1, Goal setting (behavior)***	Ask the person to use an "I will" statement to affirm or reaffirm a strong commitment (i.e. using the words "strongly", "committed" or "high priority") to start, continue or restart the attempt to take medication as prescribed
2. Feedback and monitoring			
2.1	***Monitoring of behavior by others without feedback***	Observe or record behavior with the person's knowledge as part of a behavior change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code; if feedback given, code only **2.2, Feedback on behavior**, and not **2.1, Monitoring of behavior by others without feedback**; if monitoring outcome(s) code **2.5, Monitoring outcome(s) of behavior by others without feedback**; if self-monitoring behavior, code **2.3, Self-monitoring of behaviour***	Watch hand washing behaviors among health care staff and make notes on context, frequency and technique used

2.2	***Feedback on behavior***	Monitor and provide informative or evaluative feedback on performance of the behavior *(e.g. form, frequency, duration, intensity)* *Note: if Biofeedback, code only* ***2.6, Biofeedback*** *and* *not* ***2.2, Feedback on behavior****; if feedback is on* ***outcome(s)*** *of behavior, code* ***2.7, Feedback on outcome(s) of behavior****; if there is no clear evidence that feedback was given, code* ***2.1, Monitoring of behavior by others without feedback****; if feedback on behaviour is evaluative e.g. praise, also code* ***10.4, Social reward***	Inform the person of how many steps they walked each day (as recorded on a pedometer) or how many calories they ate each day (based on a food consumption questionnaire).
2.3	***Self-monitoring of behavior***	Establish a method for the person to monitor and record their behavior(s) as part of a behavior change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code; if monitoring of outcome of behavior, code* ***2.4, Self-monitoring of outcome(s) of behavior****; if monitoring is by someone else (without feedback), code* ***2.1, Monitoring of behavior by others without feedback***	Ask the person to record daily, in a diary, whether they have brushed their teeth for at least two minutes before going to bed Give patient a pedometer and a form for recording daily total number of steps
2.4	***Self-monitoring of outcome(s) of behavior***	Establish a method for the person to monitor and record the **outcome(s)** of their behavior as part of a behavior change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code ; if monitoring behavior, code* ***2.3, Self-monitoring of behavior****; if monitoring is by someone else (without feedback), code* ***2.5, Monitoring outcome(s) of behavior by others without feedback***	Ask the person to weigh themselves at the end of each day, over a two week period, and record their daily weight on a graph to increase exercise behaviors

2.5	***Monitoring outcome(s) of behavior by others without feedback***	Observe or record outcomes of behavior with the person's knowledge as part of a behavior change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code; if feedback given, code only* ***2.7, Feedback on outcome(s) of behavior****; if monitoring behavior code* ***2.1, Monitoring of behavior by others without feedback****; if self-monitoring outcome(s), code* ***2.4, Self-monitoring of outcome(s) of behavior***	Record blood pressure, blood glucose, weight loss, or physical fitness
2.6	***Biofeedback***	Provide feedback about the body *(e.g. physiological or biochemical state)* using an external monitoring device as part of a behavior change strategy *Note: if Biofeedback, code only* ***2.6, Biofeedback*** *and not* ***2.2, Feedback on behavior*** *or* ***2.7, Feedback on outcome(s) of behaviour***	Inform the person of their blood pressure reading to improve adoption of health behaviors
2.7	***Feedback on outcome(s) of behavior***	Monitor and provide feedback on the outcome of performance of the behavior *Note: if Biofeedback, code only* ***2.6, Biofeedback*** *and not* ***2.7, Feedback on outcome(s) of behavior****; if feedback is on* ***behavior*** *code* ***2.2, Feedback on behavior****; if there is no clear evidence that feedback was given code* ***2.5, Monitoring outcome(s) of behavior by others without feedback;*** *if feedback on behaviour is evaluative e.g. praise, also code* ***10.4, Social reward***	Inform the person of how much weight they have lost following the implementation of a new exercise regime
3. Social support			
3.1	***Social support (unspecified)***	Advise on, arrange or provide social support *(e.g. from friends, relatives, colleagues,' buddies' or staff)* or non-contingent praise or reward for performance of the behavior. It includes encouragement and counselling, but only when it is directed at the **behavior** *Note: attending a group class and/or mention of 'follow-up' does not necessarily apply this BCT, support must be explicitly mentioned; if practical, code* ***3.2, Social support (practical)****; if emotional, code* ***3.3, Social support (emotional)*** (includes '**Motivational interviewing**' and **'Cognitive Behavioral Therapy'**)	Advise the person to call a 'buddy' when they experience an urge to smoke Arrange for a housemate to encourage continuation with the behavior change programme Give information about a self-help group that offers support for the behavior

3.2	***Social support (practical)***	Advise on, arrange, or provide **practical** help *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behavior *Note: if emotional, code **3.3, Social support (emotional)**; if general or unspecified, code **3.1, Social support (unspecified)** If only restructuring the physical environment or adding objects to the environment, code **12.1, Restructuring the physical environment** or **12.5, Adding objects to the environment;** attending a group or class and/or mention of 'follow-up' does not necessarily apply this BCT, support must be explicitly mentioned.*	Ask the partner of the patient to put their tablet on the breakfast tray so that the patient remembers to take it
3.3	***Social support (emotional)***	Advise on, arrange, or provide **emotional** social support *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behavior *Note: if practical, code **3.2, Social support (practical)**; if unspecified, code **3.1, Social support (unspecified)***	Ask the patient to take a partner or friend with them to their colonoscopy appointment
4. Shaping knowledge			
4.1	***Instruction on how to perform a behavior***	Advise or agree on how to perform the behavior (includes '**Skills training**') *Note: when the person attends classes such as exercise or cookery, code **4.1, Instruction on how to perform the behavior, 8.1, Behavioral practice/rehearsal** and **6.1, Demonstration of the behavior***	Advise the person how to put a condom on a model of a penis correctly
4.2	***Information about antecedents***	Provide information about antecedents (*e.g. social and environmental situations and events, emotions, cognitions)* that reliably predict performance of the behaviour	Advise to keep a record of snacking and of situations or events occurring prior to snacking
4.3	***Re-attribution***	Elicit perceived causes of behavior and suggest alternative explanations *(e.g. external or internal and stable or unstable)*	If the person attributes their over-eating to the frequent presence of delicious food, suggest that the 'real' cause may be the person's inattention to bodily signals of hunger and satiety

4.4	***Behavioral experiments***	Advise on how to identify and test hypotheses about the behavior, its causes and consequences, by collecting and interpreting data	Ask a family physician to give evidence-based advice rather than prescribe antibiotics and to note whether the patients are grateful or annoyed
5. Natural consequences			
5.1	***Information about health consequences***	Provide information (e.g. written, verbal, visual) about health consequences of performing the behavior *Note: consequences can be for any target, not just the recipient(s) of the intervention; emphasising importance of consequences is not sufficient; if information about emotional consequences, code **5.6, Information about emotional consequences**; if about social, environmental or unspecified consequences code **5.3, Information about social and environmental consequences***	Explain that not finishing a course of antibiotics can increase susceptibility to future infection Present the likelihood of contracting a sexually transmitted infection following unprotected sexual behavior
5.2	***Salience of consequences***	Use methods specifically designed to **emphasise** the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences) *Note: if information about consequences, also code **5.1, Information about health consequences**, **5.6, Information about emotional consequences** or **5.3, Information about social and environmental consequences***	Produce cigarette packets showing pictures of health consequences e.g. diseased lungs, to highlight the dangers of continuing to smoke
5.3	***Information about social and environmental consequences***	Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behavior *Note: consequences can be for any target, not just the recipient(s) of the intervention; if information about health or consequences, code **5.1, Information about health consequences**; if about emotional consequences, code **5.6, Information about emotional consequences**; if unspecified, code **5.3, Information about social and environmental consequences***	Tell family physician about financial remuneration for conducting health screening Inform a smoker that the majority of people disapprove of smoking in public places
5.4	***Monitoring of emotional consequences***	Prompt assessment of **feelings** after attempts at performing the behavior	Agree that the person will record how they feel after taking their daily walk

5.5	***Anticipated regret***	Induce or raise awareness of expectations of future regret about performance of the unwanted behavior *Note: not including* ***5.6, Information about emotional consequences****; if suggests adoption of a perspective or new perspective in order to change cognitions also code* ***13.2, Framing/reframing***	Ask the person to assess the degree of regret they will feel if they do not quit smoking
5.6	***Information about emotional consequences***	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behavior *Note: consequences can be related to emotional health disorders (e.g. depression, anxiety) and/or states of mind (e.g. low mood, stress); not including* ***5.5, Anticipated regret****; consequences can be for any target, not just the recipient(s) of the intervention; if information about health consequences code* ***5.1, Information about health consequences****; if about social, environmental or unspecified code* ***5.3, Information about social and environmental consequences***	Explain that quitting smoking increases happiness and life satisfaction
6. Comparison of behaviour			
6.1	***Demonstration of the behavior***	Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g. via film, pictures, for the person to aspire to or imitate (includes '**Modelling**'). *Note:* if advised to practice, also code, ***8.1, Behavioural practice and rehearsal;*** *If provided with instructions on how to perform, also code* ***4.1, Instruction on how to perform the behaviour***	Demonstrate to nurses how to raise the issue of excessive drinking with patients via a role-play exercise
6.2	***Social comparison***	Draw attention to others' performance to allow comparison with the person's own performance *Note: being in a group setting does not necessarily mean that social comparison is actually taking place*	Show the doctor the proportion of patients who were prescribed antibiotics for a common cold by other doctors and compare with their own data
6.3	***Information about others' approval***	Provide information about what other people think about the behavior. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do	Tell the staff at the hospital ward that staff at all other wards approve of washing their hands according to the guidelines

7. Associations			
7.1	***Prompts/cues***	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behavior. The prompt or cue would normally occur at the time or place of performance *Note: when a stimulus is linked to a specific action in an if-then plan including one or more of frequency, duration or intensity also code* ***1.4, Action planning****.*	Put a sticker on the bathroom mirror to remind people to brush their teeth
7.2	***Cue signalling reward***	Identify an environmental stimulus that reliably predicts that reward will follow the behavior (includes ***'Discriminative cue'***)	Advise that a fee will be paid to dentists for a particular dental treatment of 6-8 year old, but not older, children to encourage delivery of that treatment (the 6-8 year old children are the environmental stimulus)
7.3	***Reduce prompts/cues***	Withdraw gradually prompts to perform the behavior (includes ***'Fading'***)	Reduce gradually the number of reminders used to take medication
7.4	***Remove access to the reward***	Advise or arrange for the person to be separated from situations in which unwanted behavior can be rewarded in order to reduce the behavior (includes ***'Time out'***)	Arrange for cupboard containing high calorie snacks to be locked for a specified period to reduce the consumption of sugary foods in between meals
7.5	***Remove aversive stimulus***	Advise or arrange for the removal of an aversive stimulus to facilitate behavior change (includes ***'Escape learning'***)	Arrange for a gym-buddy to stop nagging the person to do more exercise in order to increase the desired exercise behaviour
7.6	***Satiation***	Advise or arrange repeated exposure to a stimulus that reduces or extinguishes a drive for the unwanted behavior	Arrange for the person to eat large quantities of chocolate, in order to reduce the person's appetite for sweet foods
7.7	***Exposure***	Provide systematic confrontation with a feared stimulus to reduce the response to a later encounter	Agree a schedule by which the person who is frightened of surgery will visit the hospital where they are scheduled to have surgery

7.8	***Associative learning***	Present a neutral stimulus jointly with a stimulus that already elicits the behavior repeatedly until the neutral stimulus elicits that behavior (includes **'Classical/Pavlovian Conditioning'**) *Note: when a BCT involves reward or punishment, code one or more of:* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Present repeatedly fatty foods with a disliked sauce to discourage the consumption of fatty foods
8. Repetition and substitution			
8.1	***Behavioral practice/ rehearsal***	Prompt practice or rehearsal of the performance of the behavior one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill *Note: if aiming to associate performance with the context, also code* ***8.3, Habit formation***	Prompt asthma patients to practice measuring their peak flow in the nurse's consulting room
8.2	***Behavior substitution***	Prompt substitution of the unwanted behavior with a wanted or neutral behavior *Note: if this occurs regularly, also code* ***8.4, Habit reversal***	Suggest that the person goes for a walk rather than watches television
8.3	***Habit formation***	Prompt rehearsal and repetition of the behavior in the same context repeatedly so that the context elicits the behavior *Note: also code* ***8.1, Behavioral practice/rehearsal***	Prompt patients to take their statin tablet before brushing their teeth every evening
8.4	***Habit reversal***	Prompt rehearsal and repetition of an alternative behavior to **replace** an unwanted habitual behavior *Note: also code* ***8.2, Behavior substitution***	Ask the person to walk up stairs at work where they previously always took the lift
8.5	***Overcorrection***	Ask to repeat the wanted behavior in an exaggerated way following an unwanted behaviour	Ask to eat only fruit and vegetables the day after a poor diet
8.6	***Generalisation of a target behavior***	Advise to perform the wanted behaviour, which is already performed in a particular situation, in another situation	Advise to repeat toning exercises learned in the gym when at home

8.7	***Graded tasks***	Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behavior is performed	Ask the person to walk for 100 yards a day for the first week, then half a mile a day after they have successfully achieved 100 yards, then two miles a day after they have successfully achieved one mile
9. Comparison of outcomes			
9.1	***Credible source***	Present verbal or visual communication from a credible source **in favour of or against the behavior** *Note: code this BCT if source generally agreed on as credible e.g., health professionals, celebrities or words used to indicate expertise or leader in field and if the communication has the aim of persuading; if information about health consequences, also code **5.1, Information about health consequences**, if about emotional consequences, also code **5.6, Information about emotional consequences**; if about social, environmental or unspecified consequences also code **5.3, Information about social and environmental consequences***	Present a speech given by a high status professional to emphasise the importance of not exposing patients to unnecessary radiation by ordering x-rays for back pain
9.2	***Pros and cons***	Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behavior (includes '**Decisional balance'**) *Note: if providing information about health consequences, also code **5.1, Information about health consequences**; if providing information about emotional consequences, also code **5.6, Information about emotional consequences**; if providing information about social, environmental or unspecified consequences also code **5.3, Information about social and environmental consequences***	Advise the person to list and compare the advantages and disadvantages of prescribing antibiotics for upper respiratory tract infections
9.3	***Comparative imagining of future outcomes***	Prompt or advise the imagining and comparing of future outcomes of changed versus unchanged behaviour	Prompt the person to imagine and compare likely or possible outcomes following attending versus not attending a screening appointment

10. Reward and threat			
10.1	***Material incentive (behavior)***	Inform that money, vouchers or other valued objects ***will be*** delivered if and only if there has been effort and/or progress in performing the behavior (includes **'Positive reinforcement'**) *Note: if incentive is social, code **10.5, Social incentive** if unspecified code **10.6, Non-specific incentive,** and not **10.1, Material incentive (behavior)**; if incentive is for **outcome,** code **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform that a financial payment will be made each month in pregnancy that the woman has not smoked
10.2	***Material reward (behavior)***	Arrange for the delivery of money, vouchers or other valued objects if and only if there ***has been*** effort and/or progress in performing the behavior (includes '**Positive reinforcement'**) *Note: If reward is social, code **10.4, Social reward**, if unspecified code **10.3, Non-specific reward**, and not **10.1, Material reward (behavior)**; if reward is for **outcome**, code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Arrange for the person to receive money that would have been spent on cigarettes if and only if the smoker has not smoked for one month
10.3	***Non-specific reward***	Arrange delivery of a reward if and only if there ***has been*** effort and/or progress in performing the behavior (includes '**Positive reinforcement'**) *Note: if reward is material, code **10.2, Material reward (behavior)**, if social, code **10.4, Social reward**, and not **10.3, Non-specific reward**; if reward is for **outcome** code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Identify something (e.g. an activity such as a visit to the cinema) that the person values and arrange for this to be delivered if and only if they attend for health screening

10.4	***Social reward***	Arrange verbal or non-verbal reward if and only if there ***has been*** effort and/or progress in performing the behavior (includes '**Positive reinforcement**') *Note: if reward is material, code* ***10.2, Material reward (behavior)****, if unspecified code* ***10.3, Non-specific reward****, and not* ***10.4, Social reward****; if reward is for* ***outcome*** *code* ***10.10, Reward (outcome).*** *If informed of reward in advance of rewarded behaviour, also code one of:* ***10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Congratulate the person for each day they eat a reduced fat diet
10.5	***Social incentive***	Inform that a verbal or non-verbal reward ***will be*** delivered if and only if there has been effort and/or progress in performing the behavior (includes '**Positive reinforcement'**) *Note: if incentive is material, code* ***10.1, Material incentive (behavior)****, if unspecified code* ***10.6, Non-specific incentive****, and not* ***10.5, Social incentive****; if incentive is for* ***outcome*** *code* ***10.8, Incentive (outcome).*** *If reward is delivered also code one of:* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform that they will be congratulated for each day they eat a reduced fat diet
10.6	***Non-specific incentive***	Inform that a reward ***will be*** delivered if and only if there has been effort and/or progress in performing the behavior (includes '**Positive reinforcement'**) *Note: if incentive is material, code* ***10.1, Material incentive (behavior)****, if social, code* ***10.5, Social incentive*** *and not* ***10.6, Non-specific incentive****; if incentive is for* ***outcome*** *code* ***10.8, Incentive (outcome).*** *If reward is delivered also code one of:* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Identify an activity that the person values and inform them that this will happen if and only if they attend for health screening

10.7	***Self-incentive***	Plan to reward self in future if and only if there has been effort and/or progress in performing the behavior *Note: if self-reward is material, <u>also</u> code **10.1, Material incentive (behavior)**, if social, <u>also</u> code **10.5, Social incentive**, if unspecified, <u>also</u> code **10.6, Non-specific incentive**; if incentive is for **outcome** code **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Encourage to provide self with material (e.g., new clothes) or other valued objects if and only if they have adhered to a healthy diet
10.8	***Incentive (outcome)***	Inform that a reward ***will be*** delivered if and only if there has been effort and/or progress in achieving the behavioural **outcome** (*includes **'<u>Positive reinforcement</u>'***) *Note: this includes social, material, self- and non-specific incentives for outcome; if incentive is for the **behavior** code **10.5, Social incentive**, **10.1, Material incentive (behavior)**, **10.6, Non-specific incentive** or **10.7, Self-incentive** and <u>not</u> **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform the person that they will receive money if and only if a certain amount of weight is lost
10.9	***Self-reward***	Prompt self-praise or self-reward if and only if there ***has been*** effort and/or progress in performing the behavior *Note: if self-reward is material, <u>also</u> code **10.2, Material reward (behavior)**, if social, <u>also</u> code **10.4, Social reward**, if unspecified, <u>also</u> code **10.3, Non-specific reward**; if reward is for **outcome** code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Encourage to reward self with material (e.g., new clothes) or other valued objects if and only if they have adhered to a healthy diet

10.10	***Reward (outcome)***	Arrange for the delivery of a reward if and only if there ***has been*** effort and/or progress in achieving the behavioral **outcome** (includes '**Positive reinforcement**') *Note: this includes social, material, self- and non-specific rewards for outcome; if reward is for the* ***behavior*** *code* ***10.4, Social reward****,* ***10.2, Material reward (behavior), 10.3, Non-specific reward*** *or* ***10.9****,* ***Self-reward*** *and not* ***10.10, Reward (outcome).*** *If informed of reward in advance of rewarded behaviour, also code one of:* ***10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Arrange for the person to receive money if and only if a certain amount of weight is lost
10.11	***Future punishment***	Inform that future punishment or removal of reward will be a consequence of performance of an unwanted behavior (may include fear arousal) (includes ***'Threat'***)	Inform that continuing to consume 30 units of alcohol per day is likely to result in loss of employment if the person continues
11. Regulation			
11.1	***Pharmacological support***	Provide, or encourage the use of or adherence to, drugs to facilitate behavior change *Note: if pharmacological support to reduce negative emotions (i.e. anxiety) then also code* ***11.2, Reduce negative emotions***	Suggest the patient asks the family physician for nicotine replacement therapy to facilitate smoking cessation
11.2	***Reduce negative emotions*** [b]	Advise on ways of reducing negative emotions to facilitate performance of the behavior (includes '**Stress Management**') *Note: if includes analysing the behavioural problem, also code* ***1.2, Problem solving***	Advise on the use of stress management skills, e.g. to reduce anxiety about joining Alcoholics Anonymous
11.3	***Conserving mental resources***	Advise on ways of minimising demands on mental resources to facilitate behavior change	Advise to carry food calorie content information to reduce the burden on memory in making food choices
11.4	***Paradoxical instructions***	Advise to engage in some form of the unwanted behavior with the aim of reducing motivation to engage in that behaviour	Advise a smoker to smoke twice as many cigarettes a day as they usually do Tell the person to stay awake as long as possible in order to reduce insomnia

12. Antecedents			
12.1	***Restructuring the physical environment***	Change, or advise to change the **physical** environment in order to facilitate performance of the wanted behavior or create barriers to the unwanted behavior (other than prompts/cues, rewards and punishments) *Note: this may also involve **12.3, Avoidance/reducing exposure to cues for the behavior**; if restructuring of the social environment code **12.2, Restructuring the social environment;*** *if only adding objects to the environment, code **12.5, Adding objects to the environment***	Advise to keep biscuits and snacks in a cupboard that is inconvenient to get to Arrange to move vending machine out of the school
12.2	***Restructuring the social environment***	Change, or advise to change the **social** environment in order to facilitate performance of the wanted behavior or create barriers to the unwanted behavior (other than prompts/cues, rewards and punishments) *Note: this may also involve **12.3, Avoidance/reducing exposure to cues for the behavior**; if also restructuring of the physical environment also code **12.1, Restructuring the physical environment***	Advise to minimise time spent with friends who drink heavily to reduce alcohol consumption
12.3	***Avoidance/reducing exposure to cues for the behavior***	Advise on how to avoid exposure to specific social and contextual/physical cues for the behavior, including changing daily or weekly routines *Note: this may also involve **12.1, Restructuring the physical environment*** and/or ***12.2, Restructuring the social environment***; if the BCT includes analysing the behavioral problem, only code ***1.2, Problem solving***	Suggest to a person who wants to quit smoking that their social life focus on activities other than pubs and bars which have been associated with smoking
12.4	***Distraction***	Advise or arrange to use an alternative focus for attention to avoid triggers for unwanted behaviour	Suggest to a person who is trying to avoid between-meal snacking to focus on a topic they enjoy (e.g. holiday plans) instead of focusing on food

12.5	***Adding objects to the environment***	Add objects to the environment in order to facilitate performance of the behavior *Note: Provision of information (e.g. written, verbal, visual) in a booklet or leaflet is insufficient. If this is accompanied by social support, also code **3.2, Social support (practical)**; if the environment is changed beyond the addition of objects, also code **12.1, Restructuring the physical environment***	Provide free condoms to facilitate safe sex Provide attractive toothbrush to improve tooth brushing technique
12.6	***Body changes***	Alter body structure, functioning or support **directly** to facilitate behavior change	Prompt strength training, relaxation training or provide assistive aids (e.g. a hearing aid)
13. Identity			
13.1	***Identification of self as role model***	Inform that one's own behavior may be an example to others	Inform the person that if they eat healthily, that may be a good example for their children
13.2	***Framing/reframing***	Suggest the deliberate adoption of a perspective or new perspective on behavior (e.g. its purpose) in order to change cognitions or emotions about performing the behavior (includes '**Cognitive structuring**'); *If information about consequences then code **5.1, Information about health consequences, 5.6, Information about emotional consequences** or **5.3, Information about social and environmental consequences** instead of **13.2, Framing/reframing***	Suggest that the person might think of the tasks as reducing sedentary behavior (rather than increasing activity)
13.3	***Incompatible beliefs***	Draw attention to discrepancies between current or past behavior and self-image, in order to create discomfort (includes ***'Cognitive dissonance'***)	Draw attention to a doctor's liberal use of blood transfusion and their self-identification as a proponent of evidence-based medical practice
13.4	***Valued self-identity***	Advise the person to write or complete rating scales about a cherished value or personal strength as a means of affirming the person's identity as part of a behavior change strategy (includes ***'Self-affirmation'***)	Advise the person to write about their personal strengths before they receive a message advocating the behavior change
13.5	***Identity associated with changed behavior***	Advise the person to construct a new self-identity as someone who 'used to engage with the unwanted behavior'	Ask the person to articulate their new identity as an 'ex-smoker'

14. Scheduled consequences			
14.1	***Behavior cost***	Arrange for withdrawal of something valued if and only if an unwanted behavior is performed (includes '**Response cost'**). Note if withdrawal of contingent reward code, ***14.3, Remove reward***	Subtract money from a prepaid refundable deposit when a cigarette is smoked
14.2	***Punishment***	Arrange for aversive consequence contingent on the performance of the unwanted behavior	Arrange for the person to wear unattractive clothes following consumption of fatty foods
14.3	***Remove reward***	Arrange for discontinuation of contingent reward following performance of the unwanted behavior (includes **'Extinction'**)	Arrange for the other people in the household to ignore the person every time they eat chocolate (rather than attending to them by criticising or persuading)
14.4	***Reward approximation***	Arrange for reward following any approximation to the target behavior, gradually rewarding only performance closer to the wanted behavior (includes **'Shaping'**) *Note: also code one of* ***59-63***	Arrange reward for any reduction in daily calories, gradually requiring the daily calorie count to become closer to the planned calorie intake
14.5	***Rewarding completion***	Build up behavior by arranging reward following final component of the behavior; gradually add the components of the behavior that occur earlier in the behavioral sequence (includes **'Backward chaining'**) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Reward eating a supplied low calorie meal; then make reward contingent on cooking and eating the meal; then make reward contingent on purchasing, cooking and eating the meal
14.6	***Situation-specific reward***	Arrange for reward following the behavior in one situation but not in another (includes **'Discrimination training'**) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Arrange reward for eating at mealtimes but not between meals
14.7	***Reward incompatible behavior***	Arrange reward for responding in a manner that is incompatible with a previous response to that situation (includes **'Counter-conditioning'**) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Arrange reward for ordering a soft drink at the bar rather than an alcoholic beverage

14.8	***Reward alternative behavior***	Arrange reward for performance of an alternative to the unwanted behavior (includes ***'Differential reinforcement'***) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome);*** *consider also coding* ***1.2, Problem solving***	Reward for consumption of low fat foods but not consumption of high fat foods
14.9	***Reduce reward frequency***	Arrange for rewards to be made contingent on increasing duration or frequency of the behavior (includes ***'Thinning'***) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Arrange reward for each day without smoking, then each week, then each month, then every 2 months and so on
14.10	***Remove punishment***	Arrange for removal of an unpleasant consequence contingent on performance of the wanted behavior (includes ***'Negative reinforcement'***)	Arrange for someone else to do housecleaning only if the person has adhered to the medication regimen for a week
15. Self-belief			
15.1	***Verbal persuasion about capability***	Tell the person that they can successfully perform the wanted behavior, arguing against self-doubts and asserting that they can and will succeed	Tell the person that they can successfully increase their physical activity, despite their recent heart attack.
15.2	***Mental rehearsal of successful performance***	Advise to practise imagining performing the behavior successfully in relevant contexts	Advise to imagine eating and enjoying a salad in a work canteen
15.3	***Focus on past success***	Advise to think about or list previous successes in performing the behavior (or parts of it)	Advise to describe or list the occasions on which the person had ordered a non-alcoholic drink in a bar
15.4	***Self-talk***	Prompt positive self-talk (aloud or silently) before and during the behavior	Prompt the person to tell themselves that a walk will be energising
16. Covert learning			
16.1	***Imaginary punishment***	Advise to imagine performing the **unwanted** behavior in a real-life situation followed by imagining an unpleasant consequence (includes ***'Covert sensitisation'***)	Advise to imagine overeating and then vomiting

16.2	***Imaginary reward***	Advise to imagine performing the **wanted** behavior in a real-life situation followed by imagining a pleasant consequence (includes ***'Covert conditioning'***)	Advise the health professional to imagine giving dietary advice followed by the patient losing weight and no longer being diabetic
16.3	***Vicarious consequences***	Prompt observation of the consequences (including rewards and punishments) for others when they perform the behavior *Note: if observation of health consequences, also code **5.1, Information about health consequences**; if of emotional consequences, also code **5.6, Information about emotional consequences**, if of social, environmental or unspecified consequences, also code **5.3, Information about social and environmental consequences***	Draw attention to the positive comments other staff get when they disinfect their hands regularly

[a] Notes are provided underneath most BCTs to help distinguish them from similar techniques

[b] An additional technique 'Increase positive emotions' will be included in BCT Taxonomy v2

Supplementary Table S2. Characteristics of lifestyle behavior change interventions

	Total trials (n=26)	Dietary (n=11)	Physical activity (n=8)	Lifestyle[1] (n=7)
Characteristic				
Setting[2]				
Individual	**9**	6	1	2
Combination individual and group	**7**	1	4	2
Group	**2**	1	0	1
Not specified	**7**	3	2	2
Delivery				
Face-to-face with telephone follow-up	**14**	7	6	1
Face-to-face	**7**	3	1	3
Online	**1**	0	0	1
Not specified	**3**	1	0	2
Location[2]				
Hospital/clinic	**10**	7	1	2
Home	**8**	1	4	3
Gym	**3**	0	1	2
Other[3]	**3**	1	2	0
Not specified	**6**	3	1	2
Total intervention duration				
1 month	**1**	1	0	0
3 months	**10**	3	6	1
4 to 6 months	**6**	3	1	2
12 months	**5**	1	1	3
24 to 36 months	**4**	3	0	1
Facilitator/ educator[2]				
Dietician	**12**	8	0	4
Nurse	**6**	0	1	5
Exercise physiologist/ physiotherapist	**4**	0	2	2
Psychologist	**3**	1	0	2
Social worker	**2**	0	0	2
Nephrologist	**2**	1	0	1
Researcher	**2**	2	0	0
General practitioner/medical doctor	**1**	0	1	0

[1] Any combination of diet, physical activity, weight reduction or smoking cessation
[2] Many interventions use multiple settings, locations and facilitators, therefore numbers overlap
[3] Community, physical therapy or cardiac rehabilitation centers, university premises

Volunteers/peers	**1**	1	0	0
Other[4]	**5**	0	3	2
Not specified	**4**	2	2	0
Number of facilitators				
Single	**12**	7	3	2
Multiple	**8**	2	2	4
Not specified	**6**	2	3	1
Informed by theory				
Yes	**5**	2	2	1
No	**21**	9	6	6

[4] Clinical pharmacy specialist, health educator, physical education professional, community network officer

Supplemental Table S3. Characteristics of interventions with improved outcomes

	Education	Enablement	Training	Persuasion	Environmental restructuring	Modelling	Incentivisation	Total functions
Studies with an improvement in at least one primary outcome (n=18)								
Meuleman (2016)	•	•					•	**3**
De Brito-Ashurst (2013)	•		•					**2**
MDRD Study (1995)	•	•	•	•	•	•	•	**7**
Mekki (2010)	•							**1**
Paes-Barreto (2013)	•			•		•		**3**
Pisani et al (2016)	•							**1**
Rosman (1990)	•	•						**2**
Saran (2017)	•	•						**2**
Patil (2013)	•							**1**
Flesher et al (2011)	•	•	•					**3**
Howden et al (2013)	•	•	•		•			**4**
Jiamjariyapon (2017)	•	•						**2**
Joboshi (2017)	•	•						**2**
Teng et al (2013)	•	•		•				**3**
Aoike et al (2015)	•	•	•					**3**
Kao et al (2012)	•	•	•	•				**4**
Rossi et al (2014)	•		•					**2**
Tang (2017)	•	•	•					**3**
Total studies (n,%)	**18 (100%)**	**12 (67%)**	**8 (44%)**	**4 (22%)**	**2 (11%)**	**2 (11%)**	**2 (11%)**	
Studies with no improvements in primary outcomes (n=8)								
Campbell et al (2008)	•	•						**2**
Clark (2018)		•			•			**2**
Dussol (2005)	•	•						**2**
Ishani (2016)	•	•						**2**
Greenwood (2015)		•	•		•			**3**
Barcellos (2018)		•	•					**2**
Leehey (2016)			•					**1**
Van Craenenbroeck (2015)			•					**1**
Total functions (n,%)	**3 (38%)**	**6 (75%)**	**4 (50%)**	**0**	**2 (25%)**	**0**	**0**	